2. DESCRIPTION AND COMPARISON OF ALTERNATIVES

The Mars Surveyor Program (MSP) encompasses all of NASA's Mars robotic mission activities and research undertaken to characterize the planet and its atmosphere, its geologic history, its climate and the relationship to Earth's climate change process; to determine what resource it provides for future exploration; and to search for evidence of past or present life on Mars. The MSP missions will also support data collection and technology demonstrations critical to planning and carrying our future human missions to Mars. The Mars Surveyor 2001 mission would contribute to these objectives. It would consist of an orbiter to map the surface mineralogy and elemental composition, and a lander/rover to characterize the local geology, mineralogy, and environmental conditions important to our understanding of Mars and to enabling future robotic and human exploration.

This Draft Environmental Impact Statement (DEIS) for the Mars Surveyor 2001 (MS 01) Mission evaluates the following alternatives:

- Proposed Action. NASA proposes to continue preparations for and to implement the MS 01 mission to Mars. The MS 01 mission would consist of two separate launches, one containing an orbiter spacecraft and the other containing a lander/rover spacecraft.

  NASA proposes to launch the MS 01 orbiter spacecraft from Vandenberg Air Force Base (VAFB), California in March/April 2001 onboard a Delta II 7925, and the MS 01 lander/rover spacecraft from Cape Canaveral Air Station (CCAS), Florida in April 2001 onboard a Delta II 7425. The MS 01 orbiter would remotely gather scientific data of Mars and serve as a communications link for the lander/rover. The MS 01 lander/rover would perform in situ science on the surface of Mars, exploring a potential landing site in the mid-latitude highlands of the planet for future exploration. A detailed description of the MS 01 mission can be found in Section 2.1.

- Orbiter and Lander-Only MS 01 Mission Alternative. NASA would eliminate the rover from the lander payload. All other aspects of the Proposed Action would remain the same with the MS 01 orbiter launched from VAFB in March/April of 2001, and the MS 01 lander-only spacecraft launched from CCAS in April of 2001. There would be no rover data-gathering for correlation with lander science. A detailed description of this alternative can be found in Section 2.2.

- Orbiter-Only MS 01 Mission Alternative. NASA would launch only the MS 01 orbiter spacecraft in March/April of 2001 from VAFB. Neither the MS 01 lander nor the rover would be included in this mission alternative. The MS 01 orbiter mission science objectives would otherwise be the same as described for the Proposed Action. A description of the Orbiter-Only MS 01 Mission Alternative can be found in Section 2.3.

- No-Action. Under the No-Action Alternative, NASA would discontinue preparations for the MS 01 mission to Mars.

See Figure 2-1 for MS 01 Mission Alternatives with the science objectives for each alternative (orbiter, lander, and rover) and the No-Action Alternative.

2.1 DESCRIPTION OF THE PROPOSED ACTION

The proposed MS 01 mission, consisting of an orbiter, and a lander and rover, would continue the global reconnaissance of Mars and perform surface exploration in support of the following science objectives.

1. Map the global elemental composition of the surface.
2. Acquire high spatial and spectral resolution of the surface mineralogy.
3. Determine the abundance of hydrogen in the shallow subsurface.
4. Provide information on the morphology of the Martian surface.
5. Provide high spatial resolution descent images of the selected landing site to correlate with orbital images.
6. Determine the nature of local surface geologic processes from surface morphology.
7. Determine the spatial distribution and composition of surface minerals, rocks, and soils surrounding the landing site. Correlate orbital data with lander and rover data.
8. Characterize the Martian surface radiation environment as related to radiation-induced risk to human explorers; characterize specific aspects of the Mars near-space radiation environment complementary to surface measurements.
9. Characterize the soil and dust and assess the hazard to human exploration.
10. Assess, through in situ experimentation, the feasibility of producing usable propellants from the indigenous Martian atmosphere.

The MS 01 mission would also directly contribute to NASA's goals for education and public outreach. These goals include development of special space science-related material and events for students, teachers and the general public. For the MS 01 mission, this may include allowing students from around the Nation the opportunity to become directly involved with real-time operation of the rover after its primary science mission has been completed.

2.1.1 MS 01 Orbiter

The MS 01 orbiter (see Figure 2-2) with a mass of up to 758 kilograms (kg) (1,671 pounds (lb)) including 346 kg (763 lb) of hydrazine and nitrogen tetroxide would be launched on a Delta II 7925 with an upper stage powered by a STAR 48B solid rocket motor from VAFB Space Launch Complex-2 (SLC-2) (JPL 1999). The launch period for the MS 01 orbiter launch opportunity opens March 30, 2001 and extends

MARS SURVEYOR 2001 MISSION DRAFT EIS ALTERNATIVES

Proposed Action

- Continue preparations for and implement the MS 01 with orbiter spacecraft and lander/rover spacecraft.
- Orbiter launched on a Delta II 7925 from VAFB.
- Lander/rover launched on a Delta II 7425 from CCAS.

Orbiter Objectives

- Map surface elemental abundance
- Determine localized mineralogy/petrology
- Identify sample return sites
- Study localized geologic processes
- Characterize radiation environment

Lander Objectives

- Characterize landing site geology, surface radiation environment, Martian dust/soil
- Demonstrate in situ propellant production processes, passage of Martian time
- Determine rock and soil mineralogy, mineralogy of the magnetic portion of Martian dust
- Provide high-resolution color stereo images

Rover Objectives

- Image rocks and soil; determine composition
- Monitor charge state
- Demonstrate surface traverse and sample return maneuvers

Orbiter and Lander-Only Alternative

- Continue preparations for and implement the MS 01 with orbiter spacecraft and lander-only spacecraft.
- Orbiter launched on a Delta II 7925 from VAFB.
- Lander launched on a Delta II 7425 from CCAS.

Orbiter Objectives

- Map surface elemental abundance
- Determine localized mineralogy/petrology
- Identify sample return sites
- Study localized geologic processes
- Characterize radiation environment

Lander Objectives

- Characterize landing site geology, surface radiation environment, Martian dust/soil
- Demonstrate in situ propellant production processes, passage of Martian time
- Determine rock and soil mineralogy, mineralogy of the magnetic portion of Martian dust
- Provide high-resolution color stereo images

Orbiter-Only Alternative

- Continue preparations for and implement the MS 01 with orbiter spacecraft only.
- Orbiter launched on a Delta II 7925 from VAFB.

Orbiter Objectives

- Map surface elemental abundance
- Determine localized mineralogy/petrology
- Identify sample return sites
- Study localized geologic processes
- Characterize radiation environment

No-Action

- Discontinue preparations for the MS 01 mission. Terminate mission planning.

FIGURE 2-1. DRAFT EIS ALTERNATIVES

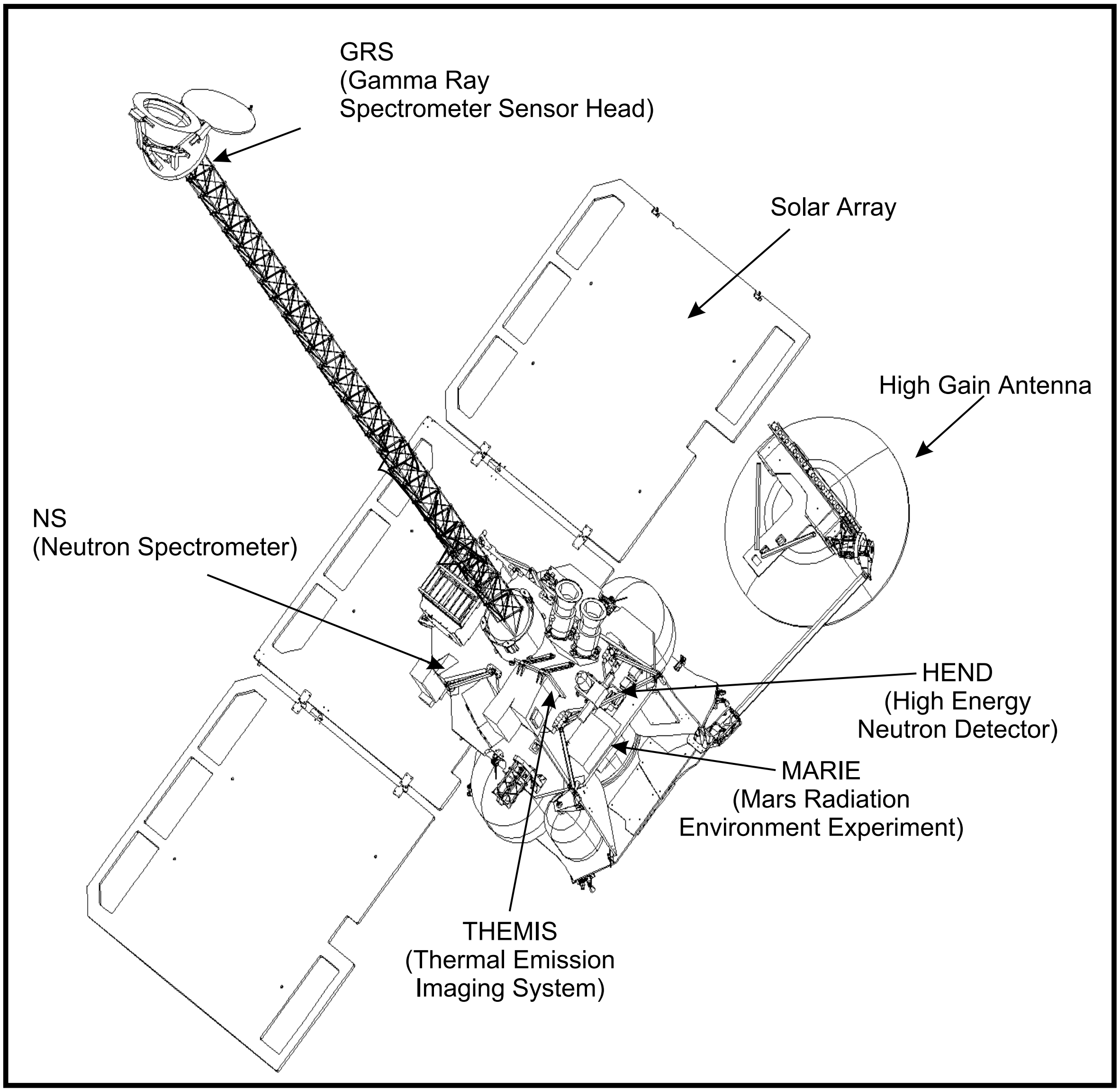


FIGURE 2-2. MS 01 ORBITER FLIGHT SYSTEM

20 days to April 18, 2001. Mars arrival dates would vary with launch dates, with the earliest anticipated arrival on October 20, 2001 when the orbiter would be captured propulsively into Mars orbit. Initially, the orbiter would be captured into a highly elliptical orbit with an orbital period of about 25 Earth hours. Once the orbiter is within the Martian atmosphere, aerobraking would place the orbiter in the desired 400 kilometers (km) (216 nautical miles (nmi)) altitude, 2-hour circular science orbit. Aerobraking is a technique that uses the planet's atmosphere to reduce the spacecraft orbital period. The spacecraft's solar panels are used as drag surfaces to reshape the orbit with each pass through the atmosphere. The spacecraft would require about 65 Earth days of aerobraking to attain the desired science orbit. Once aerobraking is complete and prior to the science phase, spacecraft systems would be checked out for about a week. During this period no science observations would occur. Science collection after this checkout period would begin in a phased approach when conditions become most favorable for a specific experiment and/or instrument.

The MS 01 orbiter would carry a Gamma Ray Spectrometer (GRS) and additional science instruments, including a radiation monitor. It would also serve as a data relay for lander/rover elements and potentially for future missions. The orbiter primary science phase would extend for 917 Earth days followed by a relay communications mission for an additional 457 Earth days. The orbiter would carry the instruments identified in Table 2-1 in support of the listed objectives.

2.1.2 <u>MS 01 Lander</u>

The MS 01 lander (see Figure 2-3) would be launched on a Delta II 7425 with an upper stage powered by a STAR 48B solid rocket motor from CCAS Launch Complex 17 (LC-17). The spacecraft would have a maximum launched mass of about 699 kg (1,541 lb) including about 64 kg (141 lb) of hydrazine, about 66 kg (145 lb) of science instruments, and a rover with a mass of about 12 kg (26 lb) (JPL 1999). Two instruments mounted on the lander would carry minor radioactive sources: the Mössbauer Spectrometer would use 1.30×10^{10} becquerels (Bq) (350 millicuries (mCi)) of cobalt (Co–57) and the radiation monitor experiment would use up to 7.40×10^{5} Bq (20 microcuries (µCi)) of curium (Cm–242) as sealed sources.

The spacecraft would consist of a cruise stage, aeroentry subsystems, and the lander carrying the rover. The aeroentry subsystems would be required to reduce the atmospheric entry velocity to safely deploy the lander to a pre-determined, near-equatorial landing site. The specific equatorial landing location would be selected approximately 9 months prior to launch (the landing latitude range would be between 3º North and 12º South). The lander launch period would open April 10, 2001 and close April 25, 2001. Mars lander arrival dates would vary with the actual launch date and would range from January 22, 2002 to February 6, 2002.

The cruise stage contains components that are used only during the cruise phase. The cruise stage has gallium arsenide deployable solar panels that generate power for the spacecraft during the cruise phase. It also contains the launch vehicle interface, communication equipment, and attitude determining sensors. The cruise stage would

TABLE 2-1. MS 01 ORBITER INSTRUMENTATION AND OBJECTIVES

Instrument	Objectives
GRS (Gamma Ray Spectrometer) with NS (Neutron Spectrometer) and HEND (High Energy Neutron Detector)	♦ Perform full planet mapping of elemental abundance on the surface by remote Gamma Ray Spectroscopy. ♦ Perform full planet mapping of hydrogen (with depth of water inferred) and carbon dioxide abundance by remote neutron spectroscopy.
THEMIS (Thermal Emission Imaging System)	♦ Determine mineralogy and petrology of localized deposits associated with hydrothermal or sub-aqueous environments and identify sample return sites likely to represent these environments. ♦ Provide a direct link to the global hyperspectral mineral mapping from the Mars Global Surveyor Thermal Emission Spectrometer. ♦ Study small-scale geologic processes and landing site characteristics using morphologic and thermophysical properties (e.g., the shape of the landscape and its characteristics in terms of rocks, dust, sand, and soil). ♦ Search for pre-dawn thermal anomalies associated with active sub-surface hydrothermal systems.
MARIE (Mars Radiation Environment Experiment)	♦ Characterize specific aspects of near-space radiation environment. ♦ Characterize surface radiation for assessing radiological risk to human exploration. ♦ Determine and model effects of the atmosphere in an attempt to predict anticipated doses and assess the atmosphere's shielding effect on the radiobiological effectiveness of incoming radiation.

be the primary platform for implementing launch vehicle separation, cruise communication equipment, and attitude control.

The aeroentry subsystems would include an aeroshell, heatshield, backshell, parachute, and terminal decent propulsion system. The aeroshell, heatshield, and backshell would protect the lander/rover during entry through the Martian atmosphere. The spacecraft would enter the Martian atmosphere directly from its interplanetary trajectory.

Just prior to Martian atmospheric entry, the lander would be separated from the cruise stage. After the lander enters Mars' atmosphere, the following events would occur in preparation for landing: the parachute would be deployed, the heatshield would be jettisoned, the Mars Descent Imager (MARDI) would be activated for descent imaging, the landing radar would be initiated, and the landing legs would be deployed. After a short coast through the atmosphere, the parachute and the backshell would be released at an optimum time as determined by the flight descent control systems. The powered descent phase would then begin. Within one kilometer (0.62 mi) of the Martian surface the terminal descent engines would fire to slow the lander descent velocity, enabling a soft landing.

Following entry, descent, and landing, the lander would deploy its silicon solar arrays, charge the lithium ion batteries and begin initial payload operations, including rover

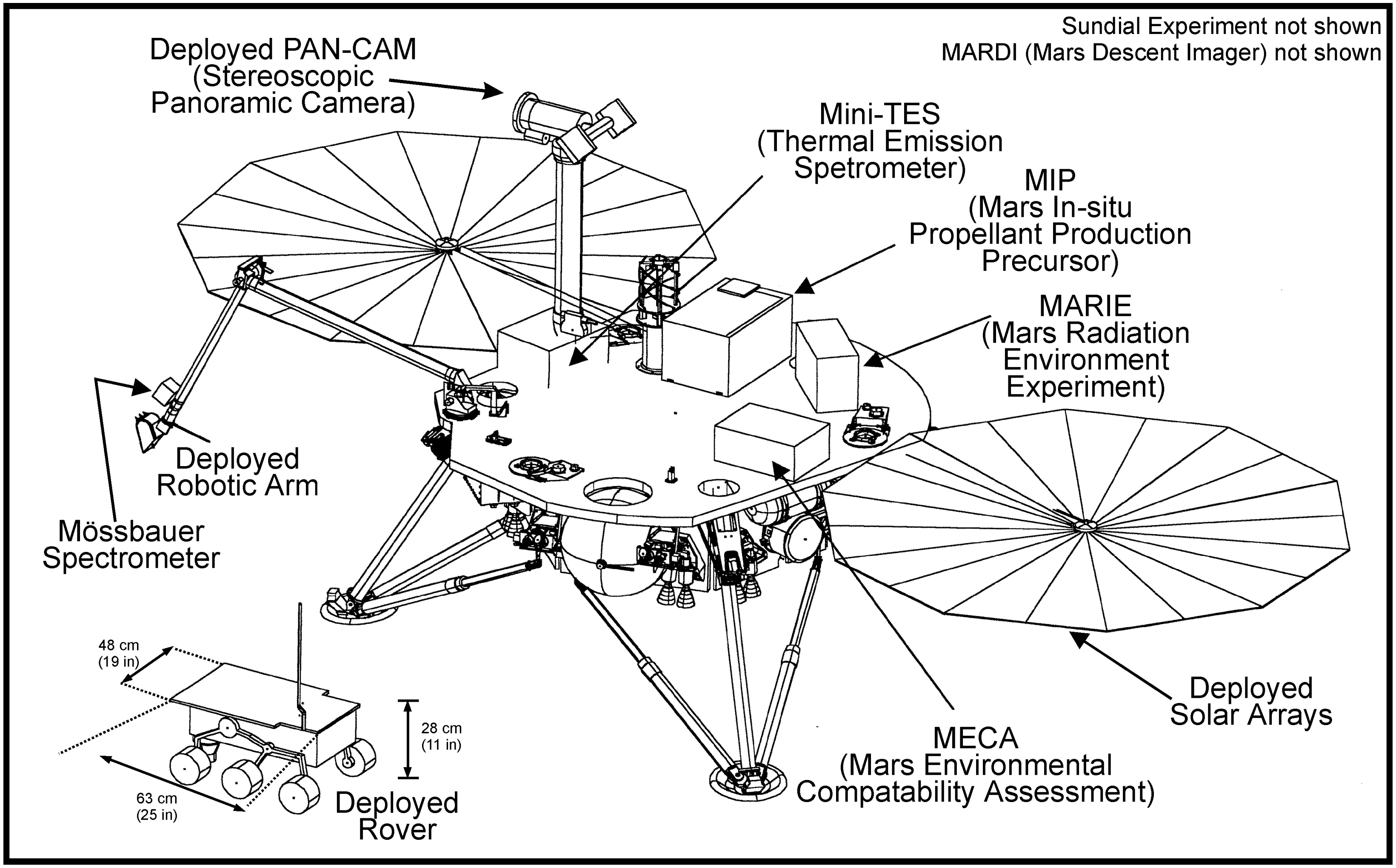


FIGURE 2-3. MS 01 LANDER DEPLOYED CONFIGURATION

deployment via the robotic arm. The lander communication equipment would be used as a relay for the rover. Once lander operations commence, its planned mission lifetime would be 90 sols (one sol equals one Martian day which equals 1.026 Earth days).

The MS 01 lander would also carry three experiments in support of NASA's Human Exploration and Development of Space (HEDS) Program objectives. The Mars Radiation Environment Experiment (MARIE) would use radiation spectrometers to characterize specific aspects of the near-space and surface radiation environment as related to radiation-induced risk to human explorers. The Mars Environmental Compatibility Assessment (MECA) experiment would characterize dust and soil (size, shape, adhesion, abrasion, and toxicity) on the surface, and identify potentially undesirable and harmful interactions with humans and crewed space systems. These experiments would be accomplished via the wet chemistry lab, the microscopy station, the material patch plates, and an electrometer. The Mars In Situ Propellant Production Precursor (MIP) experiment would demonstrate the operation of an in situ propellant production subsystem in the Martian environment. This subsystem would use a sorption compressor to absorb and compress carbon dioxide from the Martian atmosphere and use an oxygen generator to produce propellant-grade, pure oxygen by electrolyzing Martian atmospheric carbon dioxide. The MIP experiment would be the first hardware to utilize the indigenous resources of a planet or moon. In addition, it would study environmental conditions on Mars that may impact long-term propellant production operations.

The lander would carry science instruments that would form the payload suite for future larger scale rovers: the stereoscopic panoramic camera (PAN-CAM), Mini-Thermal Emissions Spectrometer (TES), and the Mössbauer Spectrometer. With the rover-mounted Alpha-Proton X-ray Spectrometer (APXS), these instruments collectively would assist in assessing the geologic and climatologic history of the landing site and provide data for the assessment of the biological potential for the region. Additionally, the lander’s robotic arm would have a camera and a scoop that would be used to dig a trench and transfer soil samples to the MECA experiment (see Table 2-2).

2.1.3 MS 01 Rover

The MS 01 rover is the engineering model of the Mars Pathfinder *Sojourner* rover upgraded for flight. The rover (see Figure 2-4) has a mass of about 12 kg (26 lb) and would be about 63 centimeters (cm) (25 inches (in)) long, 48 cm (19 in) wide, and have a deployed height of 28 cm (11 in) (NASA 1994). The rover-mounted APXS would utilize up to 3.70×10^9 Bq (100 mCi) of Cm–244 and the Mars Experiment on Electrostatic Charging (MEEC) would utilize up to 1.11×10^6 Bq (30 µCi) of americium (Am–241). The rover would use up to 3 radioisotope heater units (RHUs) for thermal control bringing the inventory of radioactive material onboard the rover to about 3.69×10^{12} Bq (99.6 Ci).

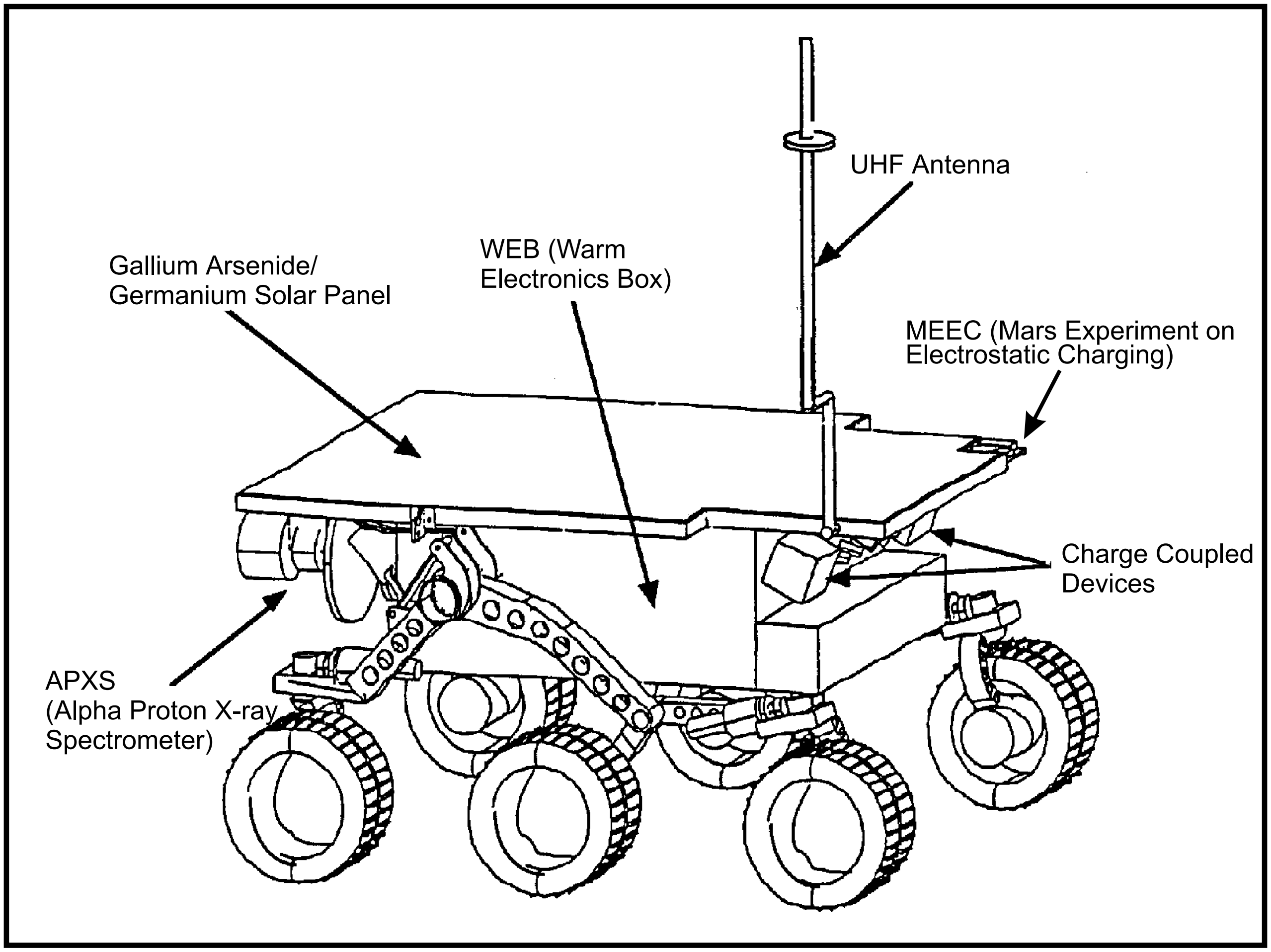
The rover would be deployed via the lander’s robotic arm and initiation of its science activities would start within one day of landing. The length of the rover primary mission

TABLE 2-2. MS 01 LANDER INSTRUMENTATION AND OBJECTIVES

Instrument	Objectives
MARDI (Mars Descent Imager)	♦ Characterize the geology of the landing site. Determine the nature of local surface geologic processes from surface morphology, and provide a link between local and regional geologic processes.
MARIE (Mars Radiation Environment Experiment)	♦ Characterize the surface radiation environment for risk to human exploration by measuring the accumulated absorbed dose and dose rate in tissue as a function of time. Determine the radiation quality factor. Determine the energy deposition spectrum. Identify the contributions of protons, neutrons, and HZE (high-atomic-number and high-energy) particles to these quantities.
MECA (Mars Environmental Compatibility Assessment)	♦ Characterize and identify hazards of the Martian environment by observation of the size, shape, and behavior of dust and soil using optical and atomic force microscopy, electrostatic sensing, and wet chemistry.
MIP (Mars In situ Propellant Production Precursor)	♦ Demonstrate operation of critical in situ propellant production subsystems and processes in the Mars environment. ♦ Absorb and compress carbon dioxide from the atmosphere. ♦ Produce propellant-grade oxygen. ♦ Characterize aspects of the Mars surface environment which will affect propellant production operations. ♦ Test thermal radiators. ♦ Test advanced photovoltaic solar cells. ♦ Test techniques to remove dust from solar cells.
Mini-TES (Thermal Emissions Spectrometer)	♦ Determine mineralogy of rocks and soil near the lander.
PAN-CAM (Stereoscopic Panoramic Camera)	♦ Provide high-resolution color stereo images.
Mössbauer Spectrometer	♦ Determine mineralogy of the magnetic portion of Martian dust.
Robotic Arm	♦ Deploy rover and dig trench for MECA experiment.
Martian Sundial	♦ Provide the colored surface as a calibration “target” for lander’s PAN-CAM to adjust brightness/tint. ♦ Demonstrate passage of local time, reveal color of the sky, and changes in seasons.

is expected to be about seven sols of surface operations. Communications with the rover would be accomplished through a relay link via the MS 01 lander and then the MS 01 orbiter. The rover would operate autonomously between communication links; since the rover is solar-powered, its mobile operations would occur only during Martian daylight hours. The rover would have surface traverse capability with a range of tens of meters over the rover mission lifetime.

The rover would gather science data by imaging rocks and soil and by deploying the APXS against Martian rock and/or soil (NASA 1994). The MEEC experiment would monitor the charge state of the rover. A dot-like piece of Am–241 would replace a solar cell on top of the rover for the MEEC experiment (see Table 2-3). Rover objectives



Source: NASA 1994

FIGURE 2-4. MS 01 ROVER

TABLE 2-3. MS 01 ROVER INSTRUMENTATION AND OBJECTIVES

Instrument	Objectives
APXS (Alpha-Proton X-ray Spectrometer)	♦ Calibration of the APXS on Mars—perform daytime and night-time calibration of APXS on calibration target. ♦ Acquire APXS measurements of soil and rock to establish baseline for PAN-CAM/Mini-TES—perform 1 rock and 1 soil APXS within rover primary mission.
MEEC (Mars Experiment on Electrostatic Charging)	♦ Monitor the charge state of the rover.

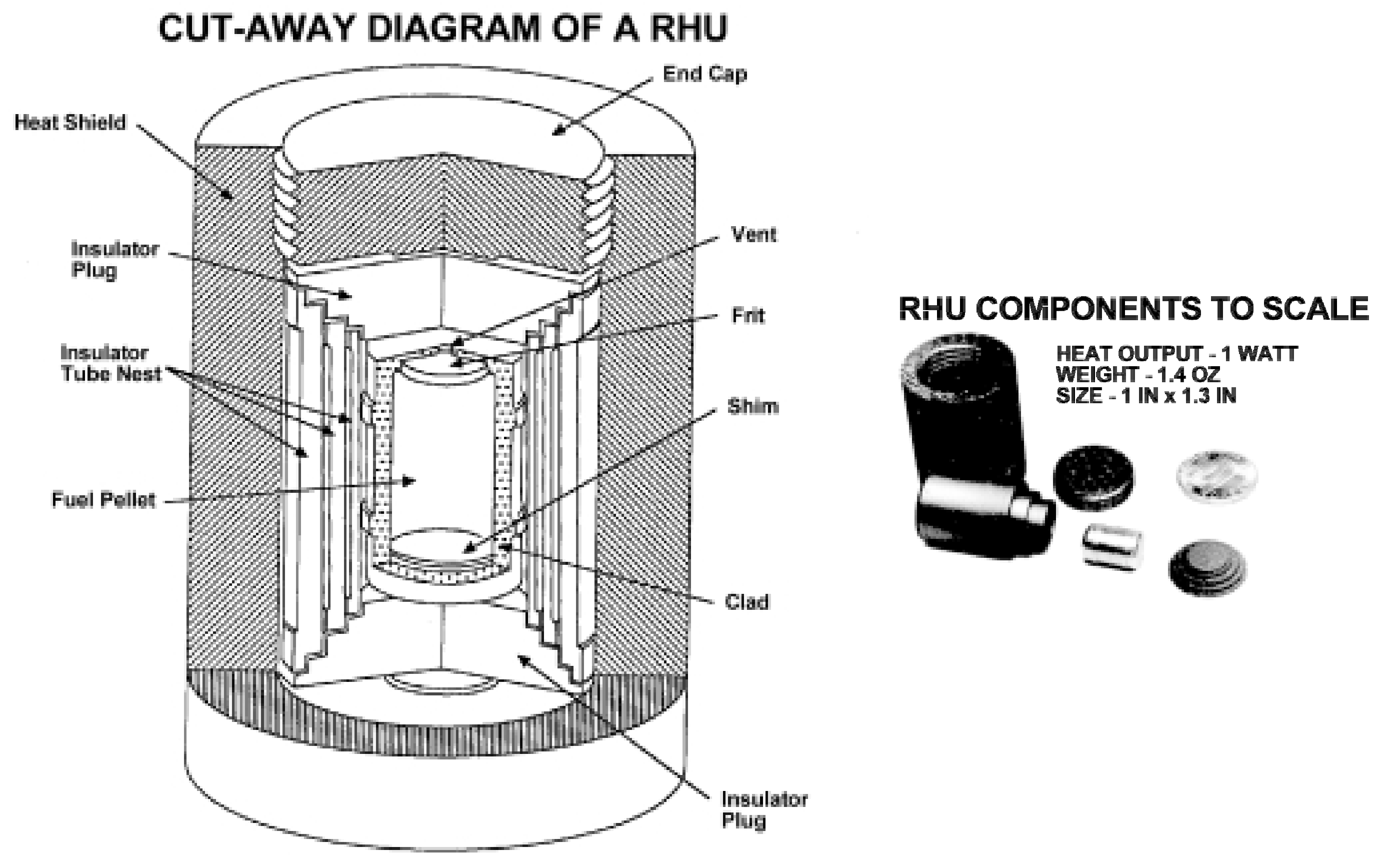
would include use of lander-based PAN-CAM images to update rover position and knowledge, and a traverse back to a specified location near the lander to demonstrate a sample return maneuver.

The rover would be powered by a gallium arsenide/germanium solar panel, mounted on top of the rover chassis. The power generated would be sufficient to power the rover for several hours of operation per day. Power would also be provided by non-rechargeable, 150 watt-hour lithium thionyl chloride batteries (JPL 1999). These lightweight, non-rechargeable batteries would be preferred because the rover mass would be severely limited. The batteries would be used to provide power for the rover during night-time operations on the Martian surface and to provide additional power when navigating rough terrain (NASA 1994).

Temperature-sensitive rover elements, such as electronics and batteries, would be enclosed in a thermally insulated Warm Electronics Box (WEB). Ideally, the WEB would be insulated to prevent internal temperatures from dropping below –40° Celsius (C) (–40° Fahrenheit (F)), the operational limit temperature for the batteries and electronic equipment. However, analysis indicates the night-time internal WEB temperature would drop to below –60° C (–76° F) and hence, the rover electronics and batteries would not likely survive one Martian night (NASA 1994). The use of three RHUs would ensure that the rover WEB temperature would be maintained in the range of –30° C to +30° C (–22° F to +86° F) keeping the instruments at operating temperature.

2.1.4 Radioisotope Heater Units

The MS 01 rover would use three lightweight RHUs to maintain internal temperature during the Martian night. Each RHU (Figure 2-5) would provide about 1 watt of heat derived from the radioactive decay of 2.7 grams (g) (0.006 lb) of plutonium (mostly Pu–238) dioxide in ceramic form. Each RHU would contribute approximately 1.23×10^{12} Bq (33.2 Ci) to the total plutonium dioxide inventory of 3.69×10^{12} Bq (99.6 Ci) on the lander/rover mission. Table 2-4 provides the typical radionuclide composition of RHU fuel (per RHU). The exterior dimensions of a RHU are 2.6 cm (1.03 in) in diameter by 3.2 cm (1.26 in) in length. Each RHU has a mass of about 40 g (0.09 lb).



Source: NASA 1995

FIGURE 2-5. THE PRINCIPAL FEATURES OF THE RADIOISOTOPE HEATER UNIT (RHU)

TABLE 2-4. TYPICAL RADIONUCLIDE COMPOSITION FOR RHU FUEL (PER RHU BASIS)

Fuel Component	Weight Percent	Half-Life (Years)	Specific Activity (Ci/g Of Fuel Component)	Total Activity (Ci)
Plutonium	85.735			
– Pu–236	0.0000010	2.851	531.3	0.00001
– Pu–238	70.810	87.75	17.12	32.7312
– Pu–239	12.859	24,131	0.0620	0.02153
– Pu–240	1.787	6,569	0.2267	0.01094
– Pu–241	0.168	14.4	103.0	0.4672
– Pu–242	0.111	375,800	0.00393	0.00001
Actinide Impurities	2.413	NA[a]	NA	NA
Oxygen	11.852	NA	NA	NA
Total	100.00	NA	NA	33.231[b]

Source: USDOE 1999

a. NA = Not Applicable
b. 1 Ci = 3.70×10^{10} Bq

RHUs are designed to be capable of containing the plutonium dioxide in both normal operations and a wide range of accident environments. The integrity and durability of RHUs are well documented (USDOE 1988). The plutonium dioxide ceramic is encapsulated in an alloy (70% platinum and 30% rhodium) container (clad). Protection against high temperature accident environments is provided by using a fine weave pierced fabric of carbon graphite compound as a heatshield (aeroshell) and a series of concentric pyrolytic graphite sleeves and end plugs to thermally insulate the encapsulated radioactive material. The RHU's fuel is also protected from ground or debris impact partially by the aeroshell and inner pyrolytic graphite insulators, but principally by the alloy clad material.

2.1.5 Payload Processing

Industrial activities associated with integrating the MS 01 lander/rover to the Delta II 7425 at CCAS and the orbiter to the Delta II 7925 at VAFB would involve routine payload activities, including receipt of components, inspection, storage, assembly, testing and transport to LC-17 and SLC-2 where the spacecraft would be mated to the Delta II. All effluents and wastes generated would be subject to Federal and State laws, regulations, and permits; CCAS and VAFB have permits and waste management programs addressing such issues. In addition, at CCAS, all radiological safety controls and precautions relating to the RHUs and other radioactive material would be strictly followed.

2.1.6 Description of the MS 01 Launch Vehicles

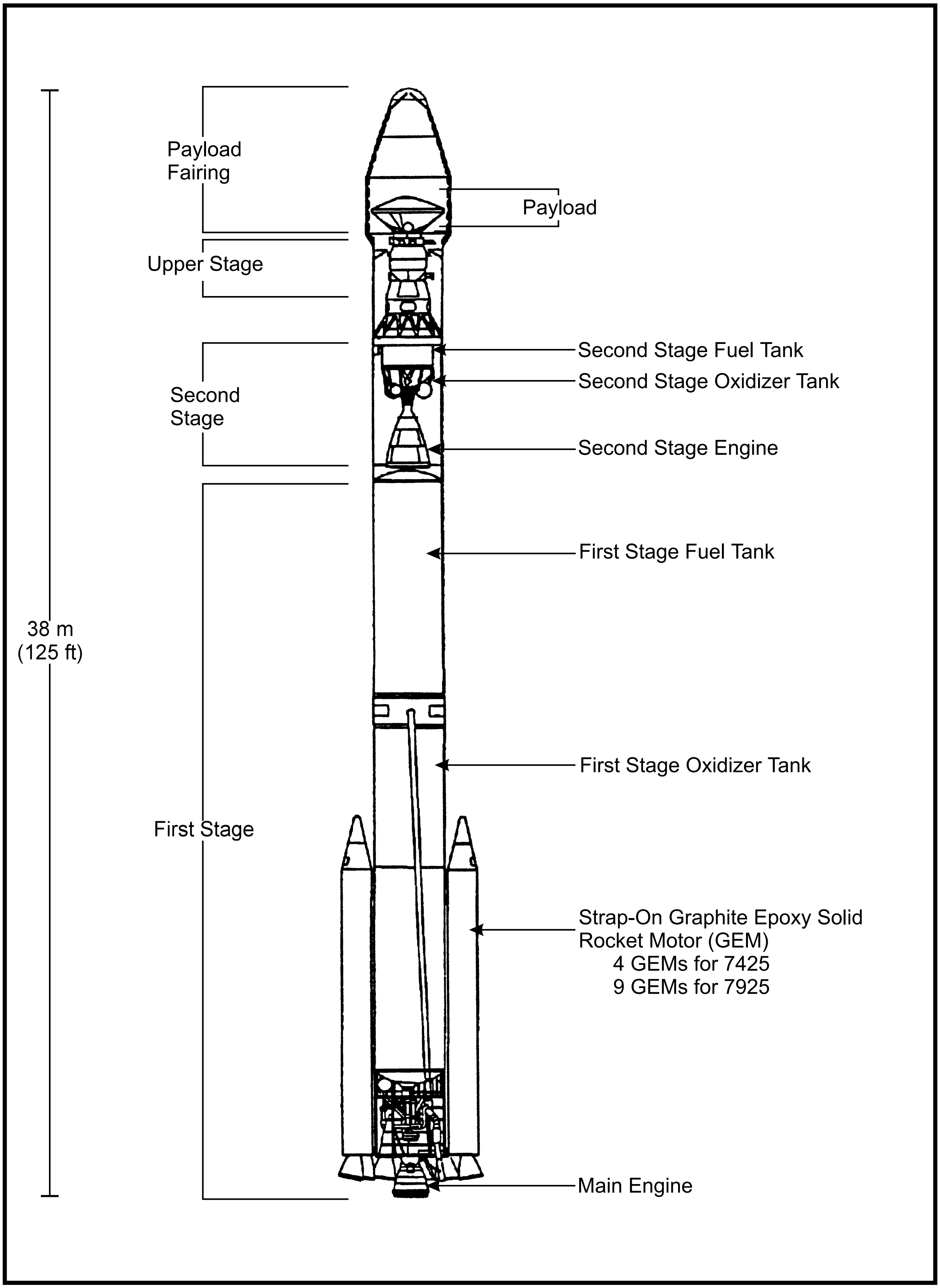
The Delta family of launch vehicles first went into service in 1960 with the launch of the Echo I satellite from CCAS. The current Delta II first saw service in early 1989 and, as of August 1999, had been utilized for 86 space launches, (70 from CCAS; 16 from VAFB). Two Delta II launch failures have occurred over this period (1995 and 1997). The first failed mission occurred when the third (upper) stage malfunctioned putting the satellite in an undesirable orbit. The second failure occurred in January 1997 and is addressed in greater detail in Section 4.1.3. The Delta II mission success rate is thus about 97.7 percent.

The Delta II 7425 and Delta II 7925 expendable launch vehicles (see Figure 2-6) would consist of first, second, and upper stage propulsion systems with graphite epoxy motors (GEMs) used as boosters to the first stage (Boeing 1996). The Delta II 7425 uses four GEMs while the Delta II 7925 uses nine GEMs. A STAR 48B solid rocket motor powers the upper stage used on both vehicles, and both employ a payload fairing (PLF) of 2.9 meters (m) (9.5 feet (ft)) in diameter.

First Stage. The Delta II 7425 and Delta II 7925 first stage would be powered by a liquid bipropellant main engine and two vernier engines. The main engine, an RS 27A, would have its thrust augmented by either four strap-on GEMs (Delta II 7425), or nine strap-on GEMs (Delta II 7925). The first stage main engine propellant load would consist of approximately 96,570 kg (212,898 lb) of rocket propellant (RP-1) fuel (thermally stable kerosene) and liquid oxygen (LOX) as an oxidizer. Each GEM would contain 11,740 kg (25,882 lb) of solid rocket fuel consisting of a mixture of ammonium perchlorate and powdered aluminum in a hydroxyl-terminated polybutadiene (HTPB) binder. The total amount of solid rocket propellant on the Delta II 7425 first stage would be 46,960 kg (103,528 lb), and on the Delta II 7925 first stage would be 105,660 kg (232,938 lb). The first stage engine and vernier engines, and in the case of the Delta II 7425 all four GEMs, would be ignited at liftoff. In the case of the Delta II 7925, six of the nine GEMs would be ignited at liftoff, with the remaining three ignited in the air. The GEM casings would be jettisoned after propellant burnout, prior to separation of the first stage.

Second Stage. The Delta II 7425 and Delta II 7925 second stage would be powered by a bipropellant AJ10-118 engine. The second stage propellant load would consist of 6,080 kg (13,404 lb) of Aerozine 50 (1:1 mix of hydrazine and unsymmetrical dimethylhydrazine (UDMH)) as fuel and nitrogen tetroxide (N_2O_4) as oxidizer.

Upper Stage. The final velocity required to insert the spacecraft into its mission trajectory would be provided by the Payload Assist Module-Delta (PAM–D) upper stage. The Delta II 7425 and Delta II 7925 upper stage is powered by a STAR 48B solid rocket motor with a propellant load of 2,010 kg (4,431 lb) of ammonium perchlorate and powdered aluminum in an HTPB binder, similar to that used in the GEMs. The STAR 48B is about 2.5 m (8 ft) in diameter and 4 m (13 ft) in length.



Source: adapted from NASA 1994

FIGURE 2-6. DELTA II 7425/7925 LAUNCH CONFIGURATION

Payload Fairing. The Delta II 7425 and Delta II 7925 both employ a payload fairing (PLF) that is 2.9 m (9.5 ft) in diameter and is constructed of aluminum. The PLF protects the spacecraft from environmental, acoustic and aerodynamic forces during the launch and ascent phases and is jettisoned from the launch vehicle during second stage powered flight.

Figure 2-7 provides the Delta II 7425 MS 01 lander/rover configuration within the PLF showing the approximate rover RHU location.

Delta II 7425 Launch Profile. The Delta II 7425 with the lander/rover would be launched from CCAS LC-17. See Table 2-5 for a typical Delta II 7425 launch vehicle ascent sequence and Figure 2-8 for a typical Delta II 7425 launch and boost profile.

Delta II 7925 Launch Profile. The Delta II 7925 with the orbiter would be launched from VAFB SLC-2. See Table 2-6 for a typical Delta II 7925 launch vehicle ascent sequence and Figure 2-9 for a typical Delta II 7925 launch and boost profile.

Launch Vehicle Processing. All launch vehicle processing activities for the MS 01 mission would be similar to those routinely practiced for other Delta II launches from CCAS and VAFB. Both CCAS and VAFB have the necessary permits and programs in place to accomplish launch vehicle processing activities in an environmentally responsible manner. The Delta II launch vehicle components would be received, inspected, stored, and processed at appropriate facilities at CCAS and VAFB. At CCAS, first and second stage destruction ordnance package processing and installation would be done at facilities approved and designated for this purpose.

Launch Complex-17/CCAS. LC-17 is located in the southwestern section of CCAS and occupies an area of about 1,438 square m (m^2) (15,460 square ft (ft^2)) and consists of two launch pads, 17A and 17B. The MS 01 lander/rover would be launched from pad 17B. LC-17 consists of a blockhouse, ready room, shops, mobile service tower, fixed umbilical tower, launch deck, exhaust flume, fuel storage tanks, and other facilities that are needed to prepare, service, and launch Delta II launch vehicles. LC-17 security is ensured by a perimeter fence, guards, access badges, and by personal escort (MDA 1997). After the January 1997 Delta II accident, blockhouse operations including launch operations were moved to a location 5 km (3 mi) southwest of LC-17. The blockhouse floor space would be used for remotely controlled spacecraft consoles and battery charging equipment (MDA 1997). The GEMs would receive all pre-launch processing in a designated Explosive Safe Area before being transported to LC-17 and attached to the first stage (NASA 1998b) (see Figure 2-10 for LC-17 layout).

Space Launch Complex-2/VAFB. SLC-2 is located on the northwest section of VAFB north of the Santa Ynez river near the ocean near Purisima Point (NASA 1993) and occupies an area of about 1.8 square km (km^2) (0.7 square mi (mi^2). SLC-2 lies inside a fenced area providing security to flight hardware processes and launch activities (NASA 1993) and has one active launch pad currently configured to launch Delta II launch vehicles. At VAFB, launch vehicle and associated components would be processed through VAFB commercial facilities. Launch vehicle components would

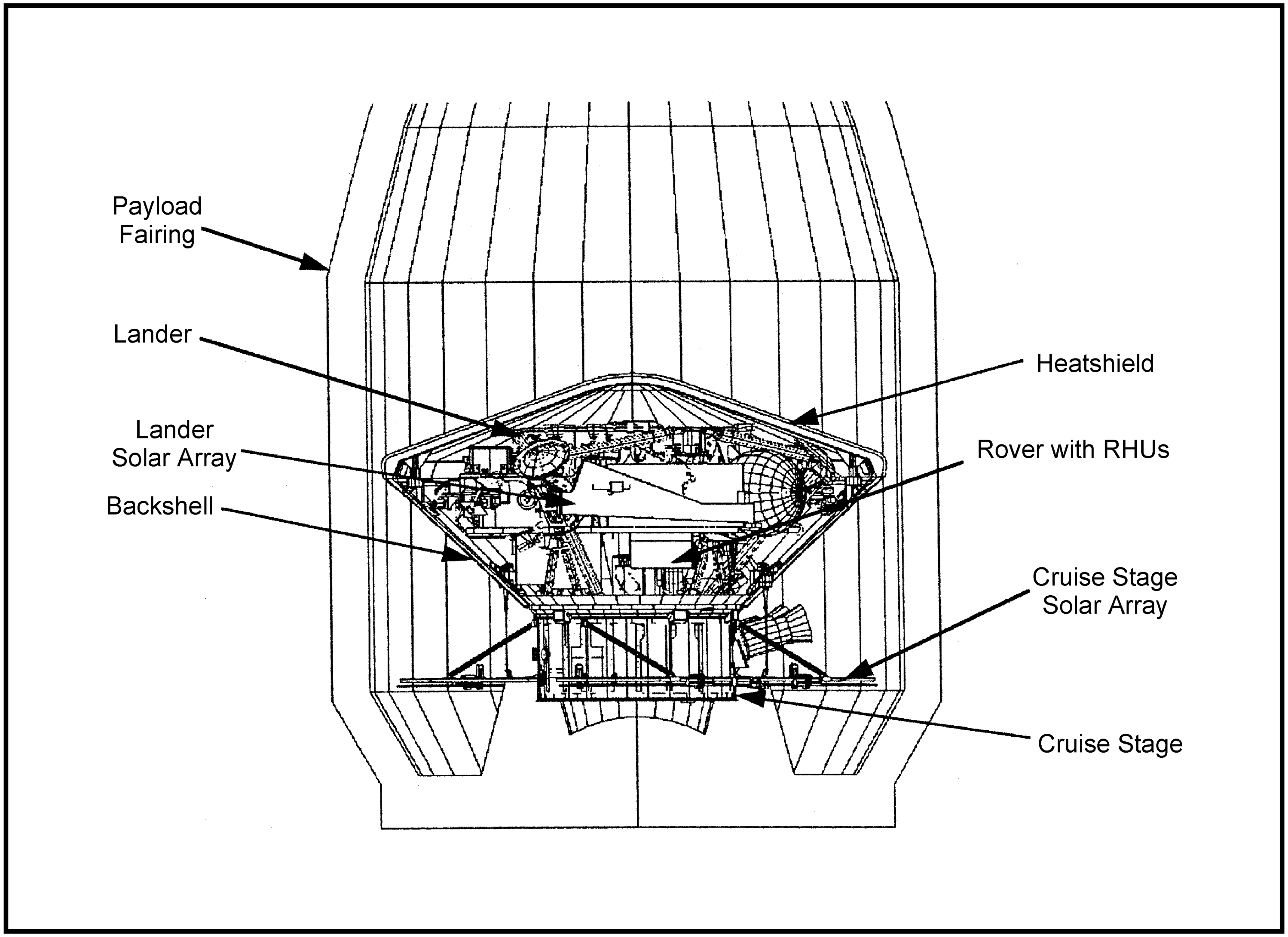


FIGURE 2-7. MS01 LANDER/ROVER LAUNCH CONFIGURATION

TABLE 2-5. TYPICAL LAUNCH VEHICLE ASCENT EVENTS FOR DELTA II 7425 FROM CCAS

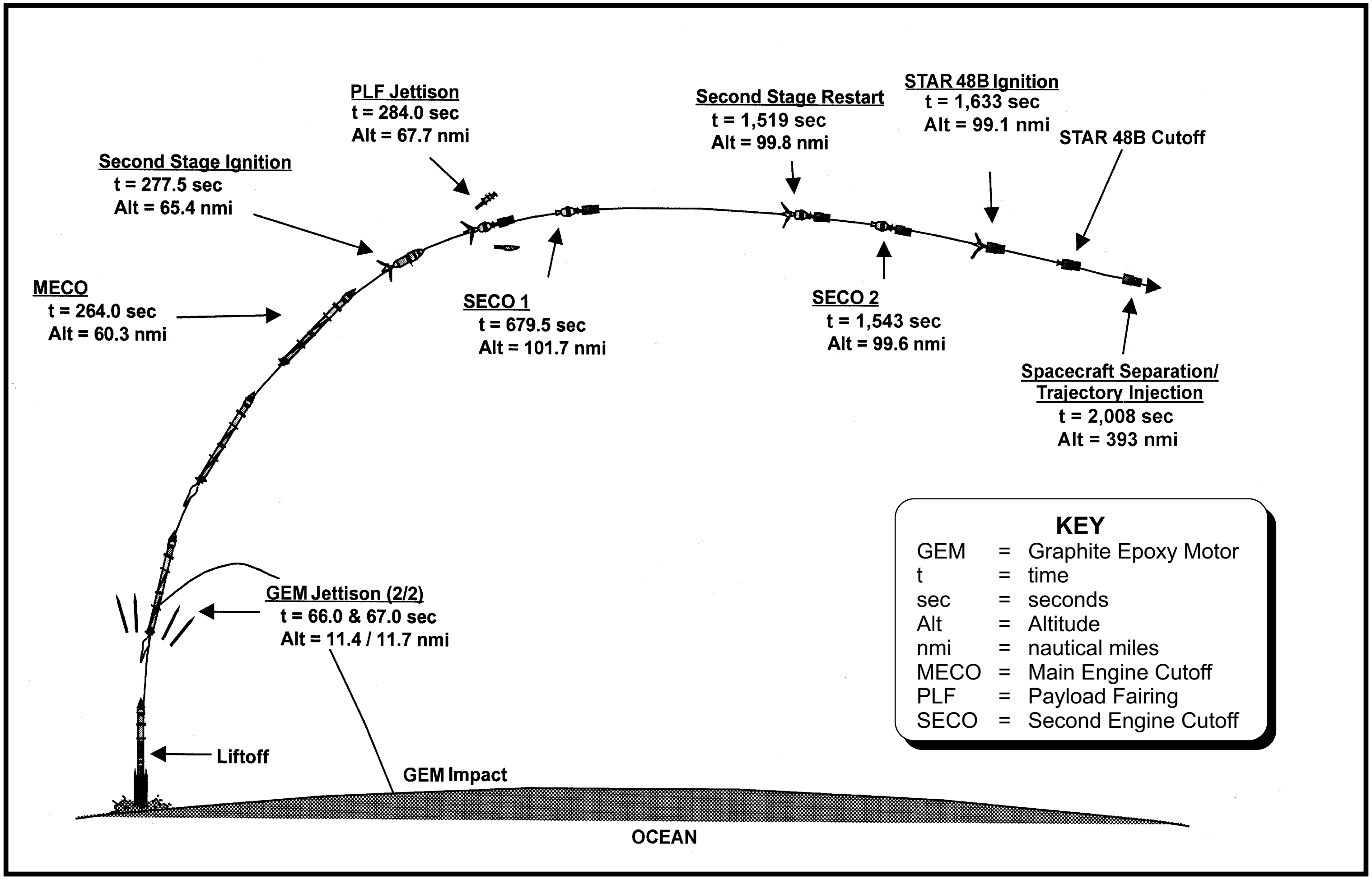
Sequence of Events	Time After Liftoff in seconds	Altitude After Liftoff in km (nmi)
Liftoff – Main Engine and GEM (4) Ignition	0	0
GEM (4) Burnout	63	
GEM (4) Jettison	66 / 67	21 / 22 (11 / 12)
Main Engine Cutoff (MECO)	264	112 (60)
First Stage / Second Stage Separation	272	
Second Stage Engine Ignition	278	121 (65)
Payload Fairing Jettison	284	125 (68)
Second Stage Engine Cutoff (SECO 1)	679	189 (102)
Second Stage Restart	1,519	185 (100)
Second Stage Engine Cutoff (SECO 2)	1,543	185 (100)
Second / Upper Stage Separation	1,596	
Upper Stage (STAR 48B) Ignition	1,633	184 (99)
Upper Stage Engine Cutoff	1,721	195 (105)
Upper Stage / Spacecraft (lander / rover) Separation	2,008	728 (393)

Source: Boeing 1996

TABLE 2-6. TYPICAL LAUNCH VEHICLE ASCENT EVENTS FOR DELTA II 7925 FROM VAFB

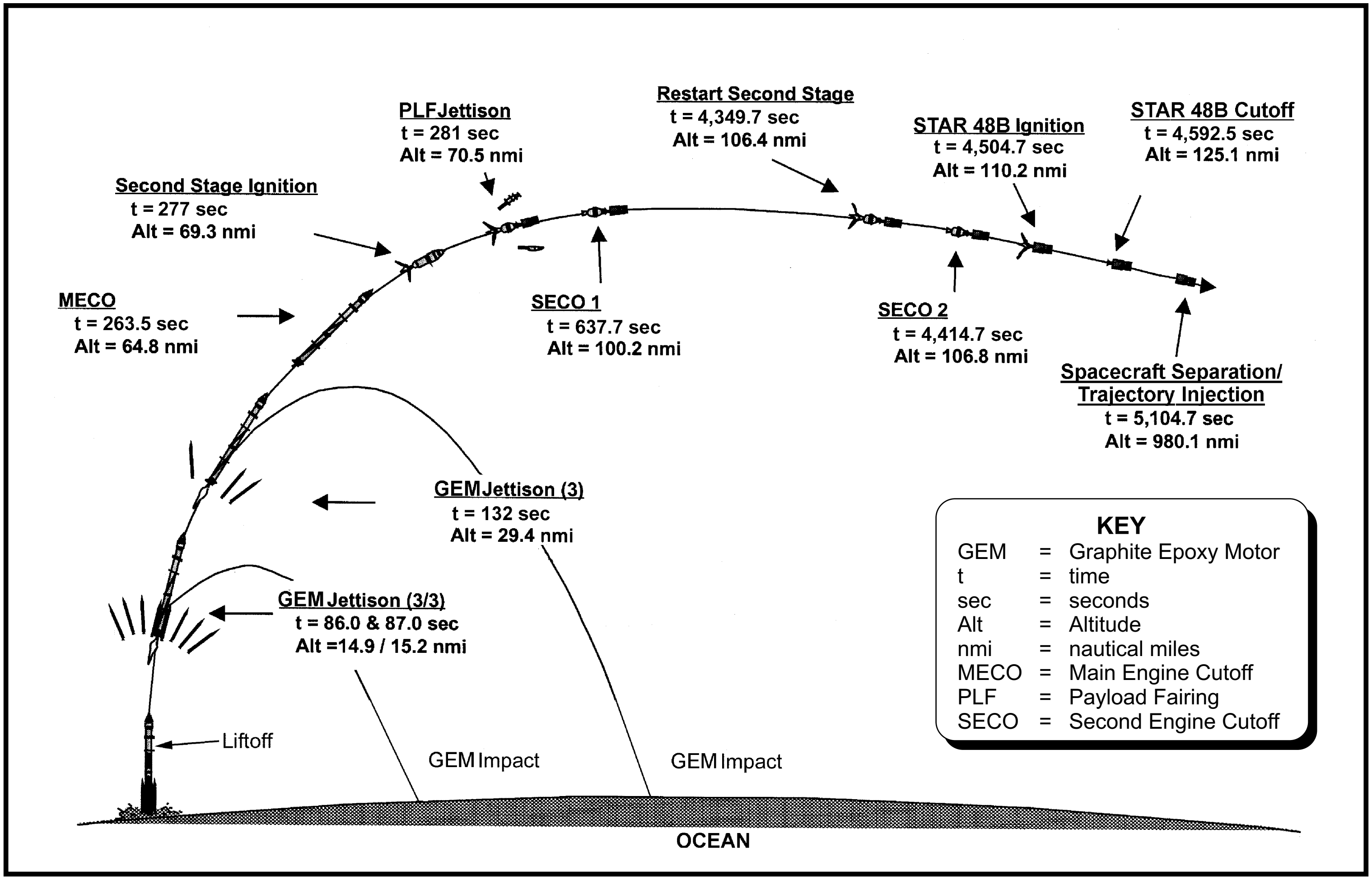
Sequence of Events	Time After Liftoff in seconds	Altitude After Liftoff in km (nmi)
Liftoff – Main Engine and GEM (6) Ignition	0	0
Ground-lit GEM (6) Burnout	64	
Air-lit GEM (3) Ignition	66	
Ground-lit GEM (3 + 3) Jettison	86 / 87	28 (15)
Air-lit GEM (3) Jettison	132	54 (29)
Main Engine Cutoff (MECO)	264	120 (65)
First Stage / Second Stage Separation	269	
Second Stage Engine Ignition	277	128 (69)
Payload Fairing Jettison	281	131 (71)
Second Stage Engine Cutoff (SECO 1)	638	185 (100)
Second Stage Restart	4,350	196 (106)
Second Stage Engine Cutoff (SECO 2)	4,415	198 (107)
Second Stage / Upper Stage Separation	4,440	
Upper Stage (STAR 48B) Ignition	4,505	204 (110)
Upper Stage Engine Cutoff	4,593	232 (125)
Upper Stage / Spacecraft (orbiter) Separation	5,105	1815 (980)

Source: Boeing 1996



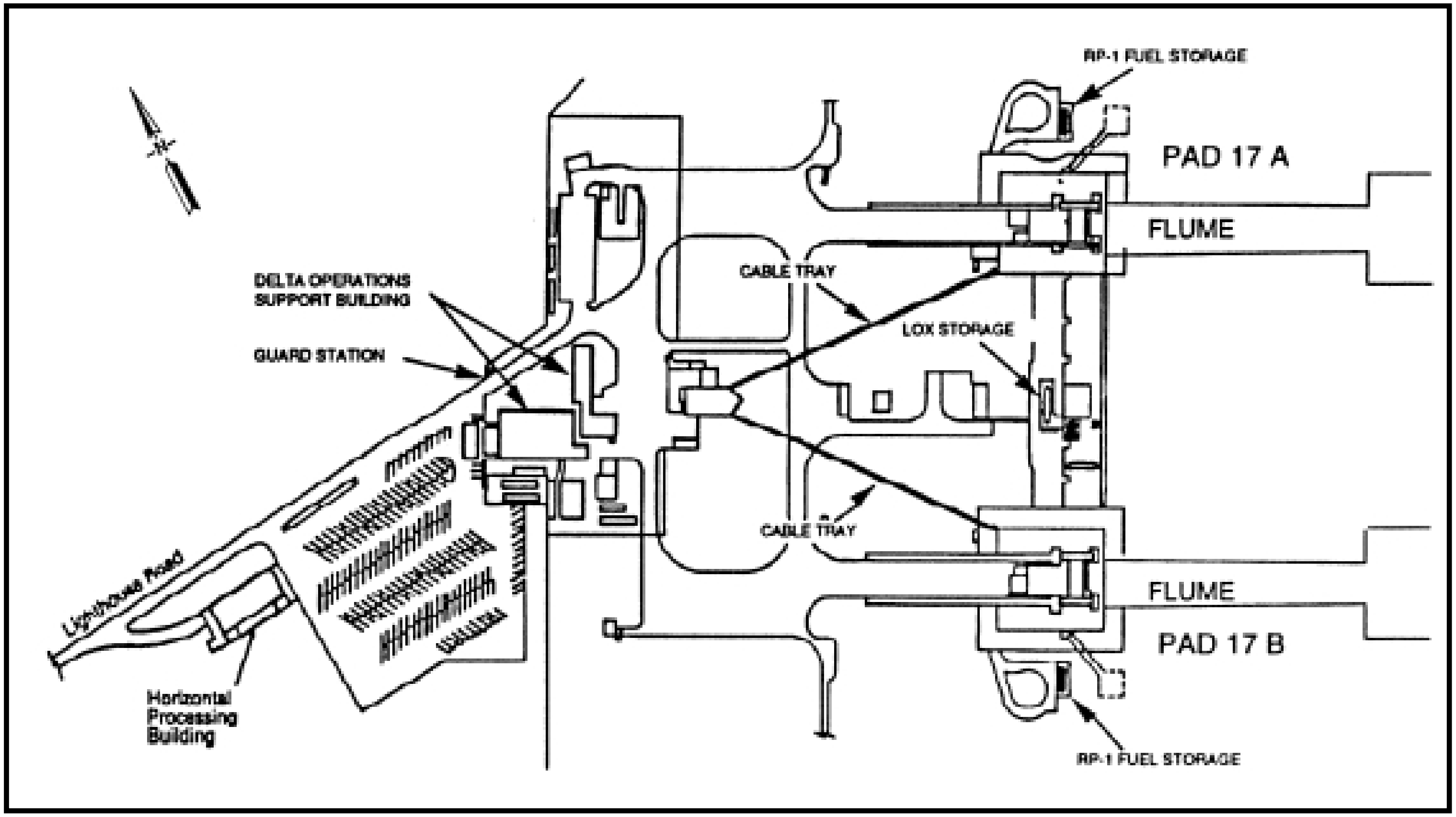
Source: adapted from Boeing 1996

FIGURE 2-8. DELTA II 7425 LAUNCH AND BOOST PROFILE



Source: adapted from Boeing 1996

FIGURE 2-9. DELTA II 7925 LAUNCH AND BOOST PROFILE



Source: adapted from USAF 1988

FIGURE 2-10. CCAS LAUNCH COMPLEX 17

be moved to the Hazardous Processing Facility for PLF processing, spacecraft buildup, GEM buildup, mating of spacecraft and GEMs, ordnance installation, and hazardous propellant loading. Once the spacecraft is flight-configured, it would be installed in a transportation handling can (i.e., a container that supports spacecraft transportation from the processing facilities to the launch pad) and transported to SLC-2 to be mated with the launch vehicle (Boeing 1996) (see Figure 2-11 for SLC-2 layout).

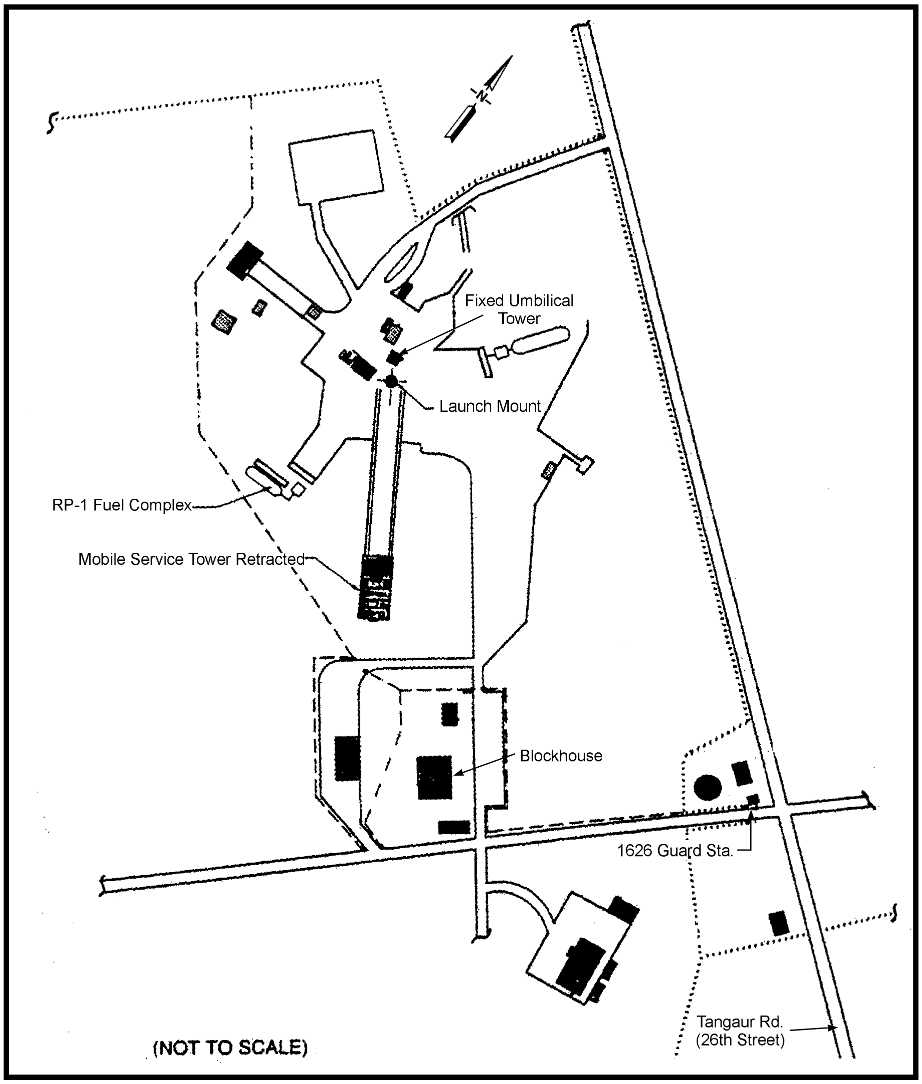
SLC-2 is supported by a launch pad, mobile service tower, fixed umbilical tower, blockhouse, Horizontal Processing Facility, solid rocket motor facility, NASA facilities, and additional facilities consisting of operational and office buildings. The launch pad consists of a launch mound, fuel storage tanks, deluge water storage tank, and flame duct.

<u>Range Safety Considerations</u>. Both VAFB and CCAS have implemented range safety programs (USAF 1997). For the MS 01 mission, a pre-determined flight safety limit would be established for the flight azimuth of each launch. Wind criteria, impacts from fragments that could be produced in a launch accident, human reaction time, data delay time, and other pertinent data are considered when determining flight safety limits. The Range Safety Officer would take necessary action including vehicle destruction if vehicle trajectory indicates flight anomalies (e.g., exceeding flight safety limits) (USAF 1997).

<u>Flight Termination System</u>. Range Safety requirements require launch vehicles to be equipped with a Flight Termination System (FTS) capable of destroying the launch vehicle. The FTS would be automatically activated or activated on a command signal issued by the Range Safety Officer. The FTS is based on electrical pathways between launch vehicle stages and would be activated when there is an interruption to the electrical pathways. For example, the FTS would be activated if an unplanned separation of the first and second stage were to occur prior to the command for first/second separation being issued from flight control.

The FTS uses explosives to destroy the launch vehicle. The first and second stages would be equipped with an electromechanical Safe & Arm device that would permit the power and sequence box to trigger vehicle destruction. Once a flight destruct signal is received, the Safe & Arm device would activate and detonate the explosives attached to the first stage fuel tank. The detonation would rupture the propellant tanks and initiate rapid burning and dispersion of propellant before the vehicle impacts the ground. The second stage Safe & Arm device would sever the second stage propellant tanks and would also activate the upper stage FTS that would rupture the upper stage motor rendering it non-propulsive.

<u>Electromagnetic Environment</u>. Aerospace launch vehicles may be subject to electromagnetic conditions such as lightning, powerful electromagnetic transmitters (e.g., radar, radio transmitters, also referred to as the electromagnetic environment), and charging effects (i.e., triboelectric charging effects (electrical charges generated by friction) and resultant electrostatic discharges). NASA and the U.S. Air Force address



Source: adapted from MDA 1996

FIGURE 2-11. VAFB SPACE LAUNCH COMPLEX-2

such conditions with respect to the design of the launch vehicle, as well as with ordnance (explosives and explosive detonators/fuses), fuels, exposed skins of the vehicle, and critical electronic systems that must have highly reliable operations. A large body of technical literature exists on these subjects and has been used by NASA and the U.S. Air Force in designing safeguards (NASA 1995).

2.2 DESCRIPTION OF THE ORBITER AND LANDER-ONLY MS 01 MISSION ALTERNATIVE

This mission alternative would be as described under the Proposed Action except there would be no rover on the MS 01 lander. NASA would delete the rover from the Proposed Action's MS 01 lander/rover spacecraft substituting about 12 kg (26 lb) of ballast on the lander to maintain spacecraft balance and control characteristics. As with the Proposed Action (see Section 2.1) the MS 01 lander-only spacecraft would be launched from CCAS in April of 2001 onboard a Delta II 7425 launch vehicle, and the MS 01 orbiter spacecraft would be launched from VAFB in March/April of 2001 onboard a Delta II 7925.

The MS 01 orbiter would remain as described for the Proposed Action in Section 2.1.1 and as illustrated in Figure 2-2. The science instrumentation and objectives of the MS 01 orbiter would remain unchanged from those described for the Proposed Action and have been summarized in Table 2-1. The MS orbiter would also retain its function as a communications link for the MS 01 lander.

Processing of the MS 01 orbiter has been described in Section 2.1.5. The Delta II 7925 launch vehicle, launch vehicle processing and the launch profile for the MS 01 orbiter would remain unchanged (see Section 2.1.6, Table 2-6 and Figure 2-9). Launch of the MS 01 orbiter would take place from SLC-2 at VAFB (Figure 2-11).

The MS 01 lander spacecraft would remain as described in Section 2.1.2, with the exception of the rover (see Figure 2-3). As with the Proposed Action, the MS 01 lander would carry two instruments that utilize minor radioactive sources: the Mössbauer Spectrometer would use 1.30×10^{10} Bq (350 mCi) of Co–57, and the radiation monitor experiment would use up to 7.40×10^{5} Bq (20 µCi) of Cm–242. There would be no RHUs in this alternative.

The details of the MS 01 lander flight to Mars and its landing and science instrument deployment would be as described in Section 2.1.2. The MS 01 lander science instrumentation and objectives would be as summarized for the Proposed Action in Table 2-2. Payload processing of the MS 01 lander would be as described in Section 2.1.5, and the Delta II 7425 launch vehicle, flight preparations, major launch events and launch profile would also be as described for the Proposed Action (see Section 2.1.6, Figure 2-6, Table 2-5, and Figure 2-8). Launch of the MS 01 lander would occur at CCAS LC-17 (Figure 2-10).

2.3 DESCRIPTION OF THE ORBITER-ONLY MS 01 MISSION ALTERNATIVE

This MS 01 mission alternative configuration would employ only the MS 01 orbiter spacecraft. The Proposed Action's lander and the rover would both be eliminated from the mission design. The MS 01 orbiter would remain as described for the Proposed Action in Section 2.1.1 and as illustrated in Figure 2-2. The science instrumentation and objectives of the MS 01 orbiter would remain unchanged from those described for the Proposed Action and summarized in Table 2-1. The Orbiter-Only Mission Alternative would accomplish about 10 percent of the overall scientific goals and objectives of the Proposed Action. Elimination of the lander and rover from the MS 01 mission design would preclude achievement of all in situ science goals and objectives envisaged for the mission. The Orbiter-Only Mission Alternative would however continue the global mapping of the Martian surface along with collection of valuable information on the elemental composition of the planet's surface and its mineralogy.

Processing of the MS 01 orbiter has been described in Section 2.1.5 and the Delta II 7925 launch vehicle, launch vehicle processing, major launch events and the launch profile for the MS 01 orbiter would remain unchanged (see Section 2.1.6, Table 2-6 and Figure 2-9). Launch of the MS 01 orbiter would take place from SLC-2 at VAFB (Figure 2-11).

2.4 DESCRIPTION OF THE NO-ACTION ALTERNATIVE

Under the No-Action Alternative, planning and preparations for the MS 01 mission would cease and neither the orbiter, lander, or rover would be launched during the 2001 opportunity. None of the science planned for the mission (Tables 2-1, 2-2, and 2-3) would be obtained. NASA has no other Mars missions at a stage of development that could be substituted for the Proposed Action or alternatives, and the favorable launch opportunity for 2001 would be lost to the Mars Surveyor Program and to NASA’s overall Mars exploration effort.

2.5 ALTERNATIVES EVALUATED BUT ELIMINATED FROM FURTHER CONSIDERATION

This section discusses alternatives that were considered but were not evaluated further. These alternatives include a discussion on reducing or eliminating plutonium heat sources, launch vehicle systems, and launch sites.

2.5.1 <u>Reduce or Eliminate Plutonium Heat Sources</u>

The MS 01 mission would use the Mars Pathfinder engineering model rover upgraded for flight. The MS 01 rover has low heat retention because of its small size and mass. The MS 01 rover electronics and batteries were qualified for operation at –40° C (–40° F) and survival at temperatures above –55° C (–67° F), well above the night-time Martian temperatures of –100° C (–148° F). The landing site for the rover would range between 3° North and 12° South latitude. The baseline mission plan requires the MS 01 rover to power the APXS instrument for almost an entire Martian night. During the night the APXS would process the readings acquired during the day when the rover would traverse the surface. Thus night-time data processing frees the rover to explore the surface during the day and to operate the APXS using its solar panels to supply power.

Thermal analyses of expected landing site temperature conditions were conducted using actual data obtained by the 1996 Pathfinder mission for the coldest landing conditions for the MS 01 rover (a 12° South latitude landing site). The thermal analyses indicated that the rover battery temperatures inside the WEB thermal enclosure would be expected to be between –25° C and –68° C (–13° F and –90° F). At this landing latitude, the coldest temperature experienced by the batteries would be colder than the qualified survival temperature of the batteries. For the warmest landing conditions expected for the MS 01 rover (3° North latitude) the thermal analyses indicated that battery temperature would drop below –20° C (–4° F) settling into a cycle ranging from –10° to –53° C (+14° to –63° F) only slightly above the survival temperature of the batteries.

Thus, the rover's electronics and batteries would not survive beyond a single Martian night without supplemental heat. To maintain rover electronics and batteries at operating temperatures, either reduction of heat loss or additional heat would need to be provided to the WEB.

Reduction of Heat Loss in the Warm Electronics Box. The MS 01 lander and rover are subject to stringent mass and volume limitations. The WEB design includes highly efficient aerogel insulation. Heat loss from the wiring between external rover elements and the WEB electronics have been minimized by using small diameter wiring. The WEB is heated by waste heat from operation of the electronics and by heaters operated from the solar panels (NASA 1994). Due to the MS 01 rover's small size there is no more room in the WEB for additional insulation. There have been no additional options identified to further reduce heat loss from the WEB.

Operating Electric Heaters with the Rover Batteries. The MS 01 rover uses 150 watt-hour, lightweight non-rechargeable batteries for its operations. Analysis indicates that the estimated battery capacity would be 150 ampere-hours at +23° C (+73° F) on the first day of operations (sol 0). Because battery capacity is a function of temperature, analysis further indicates that the rover's battery capacity would be reduced to 45 ampere-hours at –10° C (+14° F) which would be below mission requirements. Given the operating temperature limit of –40° C (–40° F), the predicted temperature profile would restrict battery operations to eight hours per sol as a best case, which would be inconsistent with the APXS operational requirements. A night-time APXS measurement would nominally require ten hours. Thus, if the rover's batteries were used to power electric heaters to maintain temperature sensitive electronics, the battery's energy would be consumed after the first night on Mars. Therefore, this would not be a feasible alternative because it would effectively end rover operations after a single Martian night, prior to the completion of its primary mission and preclude further use of the APXS instrument in gathering mission science.

Operating Electric Heaters via a Lander Power Umbilical. Electric heaters could be operated via a power umbilical from the lander to the rover for the MS 01 mission. However, interfaces between the rover and the lander must be kept as simple as possible to enhance system reliability. In addition, an umbilical would greatly restrict the range of the rover and would constitute an additional element that could potentially compromise mission success.

2.5.2 Alternate Launch Systems and Launch Sites

2.5.2.1 Launch System Selection Criteria

Selecting a launch vehicle/upper stage combination (launch system) for a planetary mission largely depends on matching the payload mass and the energy required to achieve the desired trajectory to the capabilities of the prospective launch system. The more massive the payload and the more energy required to achieve the trajectory, the more powerful the launch system required. The most desirable launch system would meet, but would not greatly exceed, the mission's minimum launch performance requirements (NASA 1994). Other considerations which must be addressed in selection of the launch system include reliability, cost, and potential environmental impacts associated with use of the launch system.

For the MS 01 mission, constraints on launch system performance are as follows. Allowable launch mass for the MS 01 orbiter would be approximately 758 kg (1,671 lbs) at the maximum injection energy of 13.5 km^2/sec^2. Allowable launch mass for the MS 01 lander/rover would be approximately 699 kg (1,540 lbs) at the maximum injection energy of 8.1 km^2/sec^2 (JPL 1999).

Feasible alternative launch systems are potentially available from both foreign and domestic manufacturers. Potential alternative launch systems from foreign manufacturers include the European Space Agency (ESA) Ariane and the Russian Proton. Potential alternative U.S. launch systems include the Space Transportation System (STS, commonly called the Space Shuttle), and various Atlas, Delta, and Titan configurations.

2.5.2.2 Foreign Launch Systems

Of the foreign launch systems that are potentially available, the ESA Ariane 44L and the Russian Proton most closely match MS 01 mission requirements for performance and injection energy. However, both of these vehicles exceed the mission requirements by a wide margin, and there is no clear environmental advantage in their use. Therefore, these foreign launch systems are not considered to be reasonable alternatives (NASA 1994).

2.5.2.3 U.S. Launch Systems

The Space Shuttle greatly exceeds the MS 01 mission requirements and would not be considered a reasonable alternative launch system.

Potential alternative U.S. expendable launch systems include the Titan IIG/STAR 48, the Delta II 7325/STAR 48, the Delta II 7425/STAR 48B, the Delta II 7925/STAR 48B, and the Atlas IIA/Centaur.

- Neither the Titan IIG/STAR 48 nor the Delta II 7325/STAR 48 meet the minimum mass performance criteria for either the MS 01 orbiter or lander/rover, and are not considered as reasonable alternatives.
- The Delta II 7425/STAR 48B meets the minimum requirements for the MS 01 lander/rover, but not for the MS 01 orbiter. The Delta II 7925/STAR 48B meets the minimum requirements for the MS 01 orbiter, but considerably exceeds the requirement for the MS 01 lander/rover.
- The Atlas IIA/Centaur greatly exceeds the launch requirements for both the MS 01 orbiter and lander/rover.

2.5.2.4 Launch Systems Summary

Of the launch systems examined, the Delta II 7925/STAR 48B is best suited for the MS 01 orbiter and the Delta II 7425/STAR 48B is best suited for the MS 01 lander/rover because each vehicle most closely matches the respective mission requirements for the lowest cost.

2.5.2.5 Launch Sites

CCAS and VAFB have the only currently approved facilities to launch Delta IIs. Since the Delta II is the preferred launch vehicle for the MS 01 mission, alternate launch sites to CCAS and VAFB would not be available.

2.6 COMPARISON OF MISSION ALTERNATIVES INCLUDING THE PROPOSED ACTION

This section summarizes and compares the potential environmental impacts of the Mars 2001 mission alternatives including the No-Action. The anticipated impacts associated with nominal or normal implementation of each alternative is considered first, followed by a summary and comparison of the potential radiological consequences and risks associated with the Proposed Action and the Orbiter and Lander-Only Mission Alternative. Neither the Orbiter-Only Mission Alternative, nor the No-Action Alternative would involve the use of radioactive material. Details summarized in this section can be found in Chapter 4, and in U.S. DOE's *Nuclear Risk Assessment for the Mars 2001 Mission Draft Environmental Impact Statement* (USDOE 1999).

2.6.1 Environmental Impacts of Normal Implementation of MS 01 Mission Alternatives and No-Action

Table 2-7 provides a summary comparison of the anticipated environmental impacts associated with normal implementation of the MS 01 mission alternatives including the No-Action Alternative.

Proposed Action

The environmental impacts associated with implementing the Proposed Action would center largely on the exhaust products emitted resulting from the Delta II launch vehicles' GEMs and the short-term impacts of those emissions. At both CCAS and VAFB high concentrations of solid rocket motor exhaust products, principally hydrogen chloride (HCl), particulates (aluminum oxide-Al_2O_3) and carbon monoxide (CO), water (H_2O), and nitrogen (N_2) would occur in the exhaust cloud that would form at each launch complex (CO and N_2 would be quickly oxidized to CO_2 and NO_x). This exhaust cloud would be buoyant and would rise quickly and begin to disperse near the launch pad. No adverse impacts to air quality in offsite areas would be expected. The exhaust from a Delta II is relatively dry, thus high concentrations of HCl would not be expected, and damage to vegetation and prolonged acidification of nearby water bodies should not occur.

If a rainstorm were to occur at the time of launch or shortly thereafter some short-term acidification of nearby water bodies could occur with the attendant potential for some mortality of aquatic biota. Biota that happened to be in the path of the exhaust could be damaged or killed. Threatened or endangered species should not be jeopardized or critical habitat effected at either CCAS or VAFB, although disturbance and incidental take could occur among California least terns and Western snowy plovers in the vicinity of the VAFB launch complex. Protected species at VAFB were addressed in a recent Biological and Conference Opinion, and incidental take permits are in place (USDOI 1999). As the launch vehicles gain altitude, a portion of the solid rocket motor exhaust (specifically HCl, Al_2O_3, and NO_X) would be deposited in the stratosphere, resulting in a short-term reduction in ozone along each vehicle's flight path. Recovery would be rapid, however.

Noise and sonic booms would be associated with launch. However, neither launch site workers nor the public would be adversely affected. No impacts to cultural, historical or archaeological resources would be expected from either launch. Neither MS 01 launch would be expected to disproportionately impact either minority or low-income populations.

Orbiter and Lander-Only Mission Alternative

The Orbiter and Lander-Only Mission Alternative would involve two Delta II launches, one each from CCAS and VAFB. The environmental impacts associated with a normal launch of each spacecraft would be the same as anticipated for the Proposed Action (see Table 2-7).

TABLE 2-7. SUMMARY COMPARISON OF THE MARS 2001 MISSION ALTERNATIVES

Impact Category	2001 Mission Alternatives			
	Proposed Action **Delta II 7425-CCAS** **Delta II 7925-VAFB**	**Orbiter and Lander-Only** **Delta II 7425-CCAS** **Delta II 7925-VAFB**	**Orbiter-Only** **Delta II 7925-VAFB**	**No-Action**
Land Use	No adverse impact on non-launch-related land uses at CCAS or VAFB.	No adverse impacts on non-launch-related land uses at CCAS or VAFB.	No adverse impacts on non-launch-related land uses at VAFB.	No change in baseline condition.
Air Quality	CCAS—High levels of GEM combustion products within the exhaust cloud as it leaves the flame trench; cloud would rise and begin to disperse near launch complex; peak concentration (0.792 ppm) of HCl around 13 km (8 mi) of launch complex. Exhaust product concentrations expected to drop rapidly with buoyant rise and mixing/dispersal of exhaust cloud. No adverse air quality impacts expected in offsite areas. VAFB— Cloud would rise and begin to disperse near launch complex; peak concentration (0.28 ppm) of HCl around 14 km (9 mi) of launch complex. GLOBAL—Not anticipated to adversely affect global climate. Temporary localized decrease in ozone along the flight path with rapid recovery.	CCAS—High levels of GEM combustion products within the exhaust cloud as it leaves the flame trench; cloud would rise and begin to disperse near launch complex; peak concentration (0.792 ppm) of HCl around 13 km (8 mi) of launch complex. Exhaust product concentrations expected to drop rapidly with buoyant rise and mixing/dispersal of exhaust cloud. No adverse air quality impacts expected in offsite areas. VAFB— Cloud would rise and begin to disperse near launch complex; peak concentration (0.28 ppm) of HCl around 14 km (9 mi) of launch complex. GLOBAL—Not anticipated to adversely affect global climate. Temporary localized decrease in ozone along the flight path with rapid recovery.	VAFB— Cloud would rise and begin to disperse near launch complex; peak concentration (0.28 ppm) of HCl around 14 km (9 mi) of launch complex. GLOBAL—Not anticipated to adversely affect global climate. Temporary localized decrease in ozone along the flight path with rapid recovery.	No change in baseline condition.
Noise and Sonic Boom	CCAS/VAFB—Short-term (5 sec) worker and public exposure to sound levels > 90 dBA; exposure levels within OSHA and U.S. EPA guidelines for affected workers and public.	CCAS/VAFB—Short-term (5 sec) worker and public exposure to sound levels > 90 dBA; exposure levels within OSHA and U.S. EPA guidelines for affected workers and public.	VAFB—Short-term (5 sec) worker and public exposure to sound levels > 90 dBA; exposure levels within OSHA and U.S. EPA guidelines for affected workers and public.	No change in baseline condition.
Geology and Soils	CCAS/VAFB—Some particulate and HCl deposition near launch complexes. No impacts to underlying geology.	CCAS/VAFB—Some particulate and HCl deposition near launch complexes. No impacts to underlying geology.	VAFB—Some particulate and HCl deposition near launch complex. No impacts to underlying geology.	No change in baseline condition.

TABLE 2-7. SUMMARY COMPARISON OF THE MARS 2001 MISSION ALTERNATIVES (continued)

Impact Category	Mission Alternatives			
	MS 01 Delta II 7425-CCAS Delta II 7925-VAFB	**Orbiter and Lander-Only** Delta II 7425-CCAS Delta II 7925-VAFB	**Orbiter-Only** Delta II 7925-VAFB	**No-Action**
Hydrology and Water Quality	CCAS— No substantial adverse long-term impacts to groundwater or surface water; potential short-term increase in the acidity of nearby surface waters. VAFB—No substantial adverse long-term impacts to groundwater or surface water; unlikely short-term increase in the acidity of nearby surface waters.	CCAS— No substantial adverse long-term impacts to groundwater or surface water; potential short-term increase in the acidity of nearby surface waters. VAFB—No substantial adverse long-term impacts to groundwater or surface water; unlikely short-term increase in the acidity of nearby surface waters.	VAFB—No substantial adverse long-term impacts to groundwater or surface water; unlikely short-term increase in the acidity of nearby surface waters.	No change in baseline condition.
Biological Resources	CCAS—Biota in launch complex could be damaged or killed during launch; possible acidification of nearby surface waters could cause some mortality of aquatic biota. No long-term adverse effects expected. No substantial short-term or long-term impact to threatened or endangered species. VAFB—Biota in launch complex could be damaged or killed; with rain following launch, short-term acidification of surface waters could cause mortality of aquatic biota. No long-term adverse effects expected. No substantial short-term or long-term impact to threatened or endangered species although incidental take could occur.	CCAS—Biota in launch complex could be damaged or killed during launch; possible acidification of nearby surface waters could cause some mortality of aquatic biota. No long-term adverse effects expected. No substantial short-term or long-term impact to threatened or endangered species. VAFB—Biota in launch complex could be damaged or killed; with rain following launch, short-term acidification of surface waters could cause mortality of aquatic biota. No long-term adverse effects expected. No substantial short-term or long-term impact to threatened or endangered species although incidental take could occur.	VAFB—Biota in launch complex could be damaged or killed; with rain following launch, short-term acidification of surface waters could cause mortality of aquatic biota. No long-term adverse effects expected. No substantial short-term or long-term impact to threatened or endangered species although incidental take could occur.	No change in baseline condition.
Socioeconomics	CCAS/VAFB—No impact expected.	CCAS/VAFB—No impact expected.	VAFB—No impact expected.	No change in baseline condition.
Cultural/Historical/ Archaeological Resources	CCAS/VAFB—No impact expected.	CCAS/VAFB—No impact expected.	VAFB—No impact expected.	No change in baseline condition.

Orbiter-Only Mission Alternative

The Orbiter-Only Mission Alternative would involve only the Delta II launch from VAFB. The expected environmental impacts for a normal launch from VAFB would be the same as described for the comparable launch under the Proposed Action (see Table 2-7).

No-Action Alternative

The No-Action Alternative would not implement any of the launches outlined for the Proposed Action, the Orbiter and Lander-Only Mission Alternative, or the Orbiter-Only Mission Alternative. Thus, none of the anticipated impacts associated with either of the normal launches or with a nonradiological launch accident would occur.

2.6.2 Environmental Impacts of Nonradiological Accidents for the MS 01 Mission Alternatives

A variety of nonradiological accidents could occur during preparation for and launch of the MS 01 spacecraft at CCAS and VAFB. The potential nonradiological impacts from a liquid fuel spill or a launch vehicle failure would be the same for the Proposed Action, and for the Lander and Orbiter-Only and the Orbiter-Only Mission Alternatives. There is no potential for such accidents to occur under the No-Action Alternative.

The potential for off-site consequences would be limited primarily to a liquid propellant (nitrogen tetroxide) spill during fueling operations of the Delta II second stage and a launch failure at or near the launch pad. U.S. Air Force safety requirements (USAF 1997) specify detailed policies and procedures to be followed to ensure worker and public safety during liquid propellant (e.g., RP-1, hydrazine) fueling operations. If a spill were to occur, rapid oxidation of the nitrogen tetroxide combined with activation of the deluge water system would limit the potential toxic effects of the propellant to the immediate vicinity of the launch pad. Workers performing propellant loading would be equipped with protective clothing and breathing apparatus and uninvolved workers would be excluded from the area during propellant loading. Propellant loading would occur only shortly before launch further minimizing the potential for accidents.

A launch vehicle failure on or near the launch area during the first few seconds of flight could result in the release of the fuels (solid and liquid) onboard the Delta II, the upper stage, and the spacecraft. The resulting emissions would resemble those resulting from a normal launch consisting principally of CO, HCl, NO_X, and aluminum oxide particulates from the burning solid rocket fuel. Liquid propellants would largely burn with some unburned propellant dispersed in the atmosphere. Some uncombusted solid and liquid propellants could enter surface water bodies and the ocean. Falling debris would be expected to land on or near the launch pad resulting in secondary ground-level explosions and localized fires. After the launch vehicle cleared land, falling debris would be expected to fall over the ocean. Modeling of accident consequences with meteorological parameters that would result in the greatest concentrations of emissions over land areas indicates that the emissions would not reach levels threatening public health. Uncombusted solid and liquid fuels entering surface water bodies could result in short-term, localized degradation of water quality and toxic conditions to aquatic life. Such fuels entering the ocean would be rapidly dispersed and buffered resulting in little long-term impact on water quality and resident biota.

The following paragraphs summarize and compare the potential consequences of launch accidents that could result in release of radioactive material with implementation of the Proposed Action and the Orbiter and Lander-Only Mission Alternative. Neither the Orbiter-Only Mission Alternative nor the No-Action Alternative would involve radioactive material.

2.6.3 Overview of the Nuclear Risk Assessment Process

The Proposed Action would involve launch of the MS 01 lander/rover spacecraft from CCAS onboard a Delta II 7425 launch vehicle employing a solid propellant STAR 48B upper stage to insert the lander/rover spacecraft into its trajectory to Mars. As noted in Section 2.1.2, the lander would be equipped with two minor radioactive sources consisting of 1.30×10^{10} Bq (350 mCi) of Co–57, and 7.40×10^{5} Bq (20 µCi) of Cm–242 as sealed instrument sources. The rover would employ two minor radioactive sources consisting of up to 3.70×10^{9} Bq (100 mCi) of Cm–244 and up to 1.11×10^{6} Bq (30 µCi) of Am–241. The rover would also employ three RHUs for thermal control totaling about 3.69×10^{12} Bq (99.6 Ci) of plutonium dioxide for a total inventory of 3.70×10^{12} Bq (100.1 Ci).

The results presented in this Mars 2001 Mission DEIS are a summarization of the assessment to date and represent the best estimate at this time of the radiological risks associated with the Proposed MS 01 mission lander/rover launch from CCAS. The details of the Proposed Action risk assessment can be found in the U.S. DOE *Nuclear Risk Assessment for the Mars 2001 Mission Draft Environmental Impact Statement* (USDOE 1999) and in Chapter 4 of this DEIS.

For the purpose of the risk assessment prepared for this DEIS, the mission was divided into four mission phases on the basis of the mission elapsed time (MET, the time [T] relative to launch) of principal events as follows:

- Phase 0 (Pre-launch, T < 0 seconds)
- Phase 1 (Launch, from T = 0 seconds, when the rocket motors are ignited, to T = 270 seconds; accidents occurring after 38 seconds would not impact land)
- Phase 2 Pre-Orbit/Orbit, from T = 270 seconds to T = 1,596 seconds)
- Phase 3 (from T = 1,596 seconds to escape from Earth orbit)

The probability of a radioactive material release as a result of an accident, the estimated quantity of radioactive material released, and the resultant dose and health effect consequences were calculated for potential launch vehicle accident scenarios that could occur within each mission phase. The accident environments considered include damage induced by propellant explosion blast waves, propellant fires, fragments, surface impacts, and, for events leading to atmospheric reentry, the thermal and structural loading effects of reentry.

Accident Probabilities and Source Terms.

Safety testing and analyses of the RHU response to accident environments indicate that, due to the protection provided by the graphitic components (the aeroshell) and platinum rhodium clad encapsulating the plutonium dioxide (PuO_2), releases due to purely mechanical damage, including overpressures and fragments, would be unlikely. The primary release mechanism would be exposure to high-temperature burning solid propellant, which could lead to clad melting and partial vaporization of the PuO_2. If the aeroshell remains intact, any vaporized PuO_2 release would be limited to that which permeates through the graphitic components of the aeroshell. Should the aeroshell be damaged or stripped, the amount of vaporized PuO_2 released would be greater (by a factor of about 100 compared to the intact aeroshell case). Thus, accident conditions leading to damaged aeroshells in proximity to burning solid propellant would be of particular importance.

The Delta II 7425 launch vehicle uses four strap-on solid propellant GEMs to augment lift capabilities of the liquid propellant main engine. In addition, the upper stage, PAM–D, is powered by a solid propellant motor, the STAR 48B. Most launch accidents in Phases 0 and 1 would lead to separation of the upper stage from the rest of the launch vehicle and result in a spacecraft and upper stage intact impact. The resulting impact could lead to mechanical damage to the RHU aeroshells, depending on the orientation at impact, and subsequent exposure to burning STAR 48B solid propellant. This, in turn, could potentially lead to PuO_2 releases.

NASA and U.S. DOE evaluated the potential accident environment in which the spacecraft and its upper stage might impact the ground as a single unit. While analyzing this situation, a conceptual separation system was considered. This conceptual separation system would function to separate the MS 01 lander/rover spacecraft from the STAR 48B upper stage in case of an accident during the first 38 seconds of the launch. This could reduce the potential for the spacecraft and upper stage to impact as a unit on or near the launch site, thereby exposing the RHUs to the intense thermal environment associated with burning solid propellant from the STAR 48B. Such a separation system would use explosive devices linked to the launch vehicle Flight Termination System to effect the separation. U.S. DOE's analysis of this conceptual system yielded small reductions in the results of the risk assessment (USDOE 1999). It was determined that such a system would not be justified, given the probable reduction in launch vehicle reliability due to added components, increased hazards associated with ordnance lines and explosives, reduction in launch vehicle lift performance due to added mass, uncertain separation system performance effectiveness, and reduced probability of overall mission success (NASA 1999). Thus the nuclear risk assessment results reported in this DEIS do not reflect incorporation of a spacecraft/upper stage separation system. Details of those analyses can be found in USDOE 1999.

In later phases of the mission through Orbit and Earth Escape, accidents could lead to reentry heating and ground impact environments. The RHU is specifically designed to survive the reentry environments. Given a post-reentry impact on a hard surface, such as rock, there would be a very small conditional probability (on the order of 10^{-5} or 1 chance in 100,000) that a PuO_2 release could occur.

The minor radioactive sources on board the spacecraft and their mounting fixtures used in spacecraft instrumentation have relatively low melting temperatures compared to PuO_2, and their release in the heated environment of a launch area accident would be likely. Reentry conditions would also likely lead to the release of the minor sources at high altitudes. For the Proposed Action risk assessment, it was determined from among the minor radioactive sources that the Co–57 source on the lander and the Cm–244 source on the rover were the main contributors to potential accident releases.

Radiological Consequence Methodology.

The radiological consequences of a given accident scenario resulting in a release of radioactive material were estimated in terms of (1) maximum individual dose; (2) collective dose; (3) health effects; and (4) for illustrative purposes, land area contaminated at or above specified levels. The maximum individual dose is the maximum dose delivered to a single individual within each accident case simulation. Collective dose is the sum of the radiation doses received by all individuals within the population exposed to radiation from a possible release.

Exposure to ionizing radiation has the potential to cause cancer and other adverse health effects. This exposure could result from the inhalation or ingestion of radioactive material or from external radiation from such material released in the environment.

Radiological consequences stemming from potential radioactive material releases have been determined from atmospheric transport and dispersion simulations incorporating both launch-site specific and worldwide meteorological and population data. These simulations estimate the distribution of radioactive material in the environment. Biological effects models, based on methods prescribed by the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP), were applied to predict the number of excess cancer fatalities (health effects) from exposures over a 50-year period following an accident resulting in a radioactive material release. Health effects are defined as the number of additional, or excess, fatal cancers (above and beyond those that would normally be expected) in the exposed population over a 50-year period.

A 50-year period represents the period of exposure to any radioactive material in the environment following a release. After 50 years, any radioactive material initially released would be essentially removed via weathering and/or tied up in soils and sediment such that exposures to people would no longer result. Also, a 50-year period is the period over which inhaled and ingested radioactive material is tracked within the body for the purpose of determining dose.

The extent of land area potentially affected by a Phase 1 accident release was also modeled by U.S. DOE. Those estimates were then compared with two types of screening levels developed by Federal agencies. The first type was a concentration level of contamination expressed in “microcuries per square meter” as derived by the U.S. EPA for illustration of contamination levels that could require some level of protective action. The other types of screening criteria were based on annual dose-rate levels that have been used by Federal agencies for clean-up actions and for regulatory purposes.

For the purpose of this DEIS, risk is defined as the expectation of health effects in a statistical sense (i.e., the product of total probability of an accident resulting in a release times the radiological consequences summed over all conditions leading to a release by accident scenario, mission phase, or overall mission).

2.6.4 Comparison of Radiological Consequences and Risks

Table 2-8 summarizes the expected (mean) potential radiological consequences and risks associated with on or near launch pad accidents resulting in a release, and the potential consequences and risks for the mission as a whole (overall mission). While accidents potentially resulting in a release of radioactive material could also occur in the later mission phases (Phase 2 and Phase 3), the on or near-pad accidents of Phase 1 (i.e., between T= 0 and T= 38 seconds) are the principal contributors to overall mission risks, accounting for about 74 percent of that risk. The expectation (mean) values are presented in Table 2-8. They represent the expected consequences and risks associated with mission accidents that could result in a release of radioactive material. U.S. DOE also developed estimates of 99th percentile consequences and risks, and those are provided in Chapter 4 of the DEIS. The 99th percentile values represent the consequences that would be exceeded 1% of the time.

The present discussion, including Table 2-8, presents numerical results in British units in summarizing the risk assessment prepared for this DEIS. The detailed discussion in Chapter 4 is presented in both Systeme International (SI) units and British units.

The Orbiter-Only Mission Alternative and No-Action Alternative would not encompass any radiological risk associated with mission accidents. The orbiter spacecraft in the Orbiter-Only Mission Alternative would have no radioactive material onboard, and the No-Action alternative would not proceed with implementing the mission. Therefore, the following paragraphs compare the Proposed Action and the Orbiter and Lander-Only Mission Alternatives.

Total Probability of Release

- Proposed Action. The total probability of a Phase 1 accident resulting in a release of radioactive material was estimated to be 3.15 x 10^{-3}, or

TABLE 2-8. COMPARISON OF POTENTIAL EXPECTATION (MEAN) RADIOLOGICAL CONSEQUENCES—PROPOSED ACTION AND ALTERNATIVES[a,b]

	Proposed Action		Orbiter and Lander-Only	
	Mission Phase 1[c]	Overall Mission[d]	Mission Phase 1[c]	Overall Mission[d]
Total Probability for Release	0.00315 (1 in 317)	0.0107 (1 in 93)	Same as Proposed Action	Same as Proposed Action
Source Term Released (curies)	0.209	0.219	0.080	0.086
Maximum Individual Dose (rem)	0.024	0.007	< 0.00001	< 0.00001
Collective (Population) Dose (person-rem)	35.6	14	0.0198	0.022
Probability of at least One Health Effect	3.0×10^{-6} 1 in 330,000	3.0×10^{-6} 1 in 330,000	$< 2.0 \times 10^{-9}$ < 1 in 500 million	$< 2.0 \times 10^{-9}$ < 1 in 500 million
Mean Health Effects	0.0175	0.00692	9.93×10^{-6} (0.00000993)	1.10×10^{-5} (0.000011)
Mission Risk	5.5×10^{-5}	7.4×10^{-5}	3.11×10^{-8}	1.18×10^{-7}
Average Individual Risk	5.5×10^{-10}	See footnote e	3.11×10^{-13}	See footnote e

Source: USDOE 1999

a. Radiological consequences are shown for only mission alternatives carrying radiological material.
b. Land area contaminated above 0.2 $\mu Ci/m^2$ would be less than 0.5 km^2.
c. Mission Phase 1 results are the mean over all mission phases launch area accidents.
d. Overall mission results are the mean over all mission phases.
e. Average individual risks are not provided because risks for different mission phases are based upon different populations and therefore, combining them for the overall mission is not appropriate.

1 chance in 317, while for the overall mission the total probability of a release would be 1.07 x 10^{-2}, or 1 chance in 93.

- Orbiter and Lander-Only Mission Alternative. For this alternative, the total probability of a Phase 1 accident resulting in a release of radioactive material would be the same as the Proposed Action. Similarly, the total probability of a release for the overall mission would be the same as the Proposed Action.

Source Term

- Proposed Action. Assuming an accident did occur, the amount of radioactive material expected to be released (source term) would be 0.209 Ci, which is a a very small fraction of the total inventory onboard the lander/rover (about 0.21 percent) in a Phase 1 accident, and 0.219 Ci (about 0.22 percent) across the overall mission. The Phase 1 source term would consist of about 60 percent from the minor sources (principally Co–57 and Cm–244); the source term for the overall mission would be similar at about 62 percent from the minor radioactive sources.

- Orbiter and Lander-Only Mission Alternative. The source term for the Phase I accident would be 0.08 Ci, while for the overall mission, the source terms would be 0.086 Ci.

Maximum Individual Dose

- Proposed Action. The maximum individual dose a member of the exposed population would be expected to receive over a 50-year period would be about 0.024 rem in a Phase 1 accident, and about 0.007 rem for the overall mission. To put these doses in perspective, the average individual living in the United States receives a dose of background radiation of about 0.300 rem/yr, or about 15 rem over a 50-year period. Thus, the maximally exposed individual, in the event of a Phase 1 accident, would receive over a 50-year period about 0.16 percent of the total 50-year exposure to average background radiation.

- Orbiter and Lander-Only Mission Alternative. The maximum individual dose was estimated to be less than 0.00001 rem for both a Phase 1 accident and the overall mission.

Collective (Population) Dose

- Proposed Action. A Phase 1 accident resulting in a release would be expected to result in a total collective (population) dose of about 35.6 person-rem. For the overall mission, across all mission phases, the expectation (mean) value of the collective dose would be about 14 person-rem.

- Orbiter and Lander-Only Mission Alternative. Correspondingly smaller collective (population) doses would be expected for this alternative as compared to the Proposed Action. The expected Phase 1 collective dose at 0.0198 person-rem would be a small fraction of that estimated for the Proposed Action, as would the collective dose expected for the overall mission at 0.022 person-rem.

Probability of At Least One Health Effect

- Proposed Action. The probability of at least one excess cancer fatality associated with the Proposed Action would be about 3×10^{-6}, or about 1 in 330,000.
- Orbiter and Lander Only Mission Alternative. The probability of at least one excess cancer fatality from this mission alternative would be less than 2.0×10^{-9}, or about 1 in 500 million.

Expectation (Mean) Health Effects

- Proposed Action. Applying the ICRP biological model used for workers and the general public, the expected number of excess cancer fatalities within the exposed population would be about 0.0175 for Phase 1, and about 0.0069 for the overall mission.
- Orbiter and Lander-Only Mission Alternative. The corresponding number of health effects (excess cancer fatalities over a 50-year period) expected for this alternative would be 0.00000993 for a Phase 1 accident and 0.000011 for the overall mission.

Mission Risk

- Proposed Action. The Phase 1 risk for the Proposed Action would be the total probability of release (3.15×10^{-3}) multiplied by excess cancer fatalities (0.0175), yielding a Phase 1 mission risk of 5.5×10^{-5}. Using the same process, the overall mission risk for the Proposed Action would be 7.4×10^{-5}.
- Orbiter and Lander-Only Mission Alternative. Given the smaller radiological inventory onboard the lander and the smaller expected number of health effects within the potentially exposed populations, the Phase 1 and mission risk would be 3.11×10^{-8} and the overall mission risk would be 1.18×10^{-7} (see Table 2-8).

Average Individual Risk

- Proposed Action. The average individual risk within Phase 1 is provided for the Proposed Action in Table 2-8. The average individual risk represents the risk to the average individual within the potentially exposed population. The average individual risk for Phase 1 would be the Phase 1 risk (5.5×10^{-5}) divided by the potentially exposed population (on the order of 100,000 people). This computation results in a Phase 1 average individual risk of 5.5×10^{-10}.

- Orbiter and Lander-Only Mission Alternative. Given the smaller Phase 1 risk associated with the Orbiter and Lander-Only Mission Alternative, the average individual risk for the Phase 1 accident (3.11×10^{-13}) would be correspondingly smaller.

For illustrative purposes, Table 2-9 presents information on annual fatality risk to populations and to average individuals in the population from various types of hazards.

Land Contamination

For estimates of potential land contamination associated with Phase 1 launch area accidents, U.S. DOE performed a more detailed analysis on a sample of the modeling performed for the Phase 1 consequence analyses. The more detailed analysis resulted in estimates of the area of potential land contamination that were then compared with two types of illustrative screening levels that have been used by Federal agencies for clean-up and regulatory actions. One set of screening levels used land area contamination (based on concentration levels of 0.1 $\mu Ci/m^2$ and 0.2 $\mu Ci/m^2$) has been suggested for determining whether further action should be evaluated, including monitoring and remedial actions. The second set, used for illustrative comparison, consisted of risk-based annual dose rates (15, 25, and 100 mrem/yr) that have been used for determining acceptable clean-up levels and other regulatory actions.

U.S. DOE determined that less than 0.5 km^2 of dry land area would be contaminated above U.S. EPA concentration screening level. In addition, debris in areas near the launch pad would include intact RHUs and potentially, fuel pellets.

In comparing the modeling results with the dose rate screening levels, some modeling results indicated that there would be some dry land areas greater than 1 km^2 in size where the dose rates over the first year would exceed all of the screening levels. In all cases, however, the modeling indicated that after the first year the dose rates within all those areas would fall below the dose rate-based screening levels. If an accident should occur, the potential extent and levels of contamination would be determined and the appropriate response actions would be initiated.

Uncertainty

Uncertainty analyses performed for previous mission safety analyses have shown that parameter and model uncertainties associated with source terms, probabilities, and radiological consequences could result in risk estimates that vary from one to two orders of magnitude at the 5 and 95 percent confidence levels.

Uncertainty exists in the potential for release of PuO_2 if burning solid propellant is nearby. NASA, U.S. DOE, and their contractors have used the best available information to determine the conditional probabilities that a release might occur and the amount, form, and particle size of PuO_2 that might be released. Analysis of the January

TABLE 2-9. CALCULATED INDIVIDUAL RISK OF FATALITY BY VARIOUS CAUSES IN THE UNITED STATES[a]

Accident Type	Number of Fatalities	Approximate Individual Risk Per Year
Motor Vehicle	43,363	1.65×10^{-4}
Suicide	31,300	1.19×10^{-4}
Homicide and Legal Intervention (Executions)	22,900	8.71×10^{-5}
Falls	13,986	5.32×10^{-5}
Accidental Poisoning, includes drugs/medicines, other solid and liquid substances, gases, and vapors	9,072	3.45×10^{-5}
Drowning	3,790	1.44×10^{-5}
Fires and Flames	3,761	1.43×10^{-5}
Suffocation	2,095	7.76×10^{-6}
Guns, Firearms, and Explosives	1,225	4.66×10^{-6}
Air Travel	851	3.24×10^{-6}
Water Transport	762	2.90×10^{-6}
Manufacturing[b]	743	2.77×10^{-6}
Railway	569	2.16×10^{-6}
Electrocution	559	2.13×10^{-6}
Lightning	85	3.23×10^{-7}
Floods and Flash Floods	80	3.04×10^{-7}
Tornadoes	30	1.14×10^{-7}
Hurricanes	17	6.46×10^{-8}
All Accidents	92,429	3.51×10^{-4}
Diseases	2,164,600	8.23×10^{-3}
All Causes	2,312,100	8.79×10^{-3}

Sources: BLS 1998; NOAA 1995; USBC 1998b

a. Based on 1995 statistics and a population of 263,039,000.
b. Based on 1997 statistics and a population of 267,901,000.

1997 CCAS Delta II accident included hydrodynamic modeling of the effects of propellants under accident conditions and the probable response of the RHUs to the blast, fragment, and thermal environments associated with that accident.

2.6.5 Comparison of the Science Returns for the Mission Alternatives

The Proposed Action. The Proposed Action would have a substantial positive impact on the planning and implementation of future Mars Surveyor missions and to the broader strategy for Mars exploration. These contributions would be achieved through the carefully planned architecture for the mission with its orbiter, lander, and rover, and their associated science packages. Each of these major mission elements individually would return valuable scientific data and observations. However, functioning together as an integrated whole in which each of these three science platforms complement the other, the scientific contributions to exploration of the planet Mars and to future mission planning and implementation would be multiplied.

The MS 01 orbiter would perform full planet mapping of surface features and characteristics, as well as the surface mineralogy of Mars on a global basis. The orbiter would also provide global-level information on geological processes and the potential existence of liquid water beneath the planet's surface. This data would enhance planning and design of future missions by assisting scientists and mission designers to maximize the "value added" of science payloads and specific mission objectives. In addition, the information gathered by the orbiter on characteristics of the global radiation environment would contribute to planning of potential human exploration of the planet at some point in the future. The orbiter would also serve as an essential communication link between the lander and rover on the planet's surface and mission controllers on Earth. Mission controllers would transmit commands to the lander and rover, and use the orbiter communication link to diagnose and correct problems that may occur. All scientific data acquired by the lander and rover would be transmitted to Earth via the orbiter.

The instrument packages that would be on the lander would complement those on the orbiter, provide scientific data necessary to satisfy the objectives set out for the MS 01 mission, and would also make substantial contributions to future mission planning and design. Scientists would be able to verify or "ground truth" the physical, geological, and chemical characteristics of the landing site described by the orbiter thus enhancing the present and future value of orbital data gathering. The science packages on the lander would, in turn, complement each other. The lander payload has been carefully selected to maximize collection of scientific data to meet lander mission objectives. Landing site characterization information obtained by the Panoramic Camera's high resolution stereographic images, for example, would be used to target data collection activities by other science packages on both the lander and the rover in the acquisition of site-specific mineralogical data. This data, in turn, would be used to target other science instruments and activities, such as acquisition of subsurface samples for analysis onboard the lander. Among the lander science packages would be instruments that would collect data on the radiation environment at the planet's surface, as well as assist in determining the potential for propellant production using carbon dioxide in Mars' atmosphere. This information would be of substantial benefit if our Nation were to proceed with human exploration of the planet in future years.

The rover, as well, would complement the other science packages onboard the lander. The rover, using information obtained by the mineralogical instruments, would be directed to specific locations to determine the chemical composition of sites or features of interest. Operation of the rover and its science payload would also benefit the planning and design of future missions. The instruments onboard the rover would be the precursors to those that are planned for use on large-scale rovers for future missions. In addition, the MS 01 rover operation would also serve to refine navigation techniques for future large-scale rover operations.

The Proposed Action would meet all objectives established for the MS 01 mission, providing a wide range of integrated and complementary scientific observations. The scientific objectives for the MS 01 mission are targeted at providing necessary data and information for planning future Mars Surveyor missions as well as other future exploration initiatives.

Assessment of the Orbiter and Lander-Only Mission Alternative. Removal of the rover from the MS 01 mission would eliminate the capability to achieve the stated science objective to “determine the spatial distribution and composition of surface minerals, rocks, and soils surrounding the landing site” (see Section 2.1). The rover's APXS instrument provides the elemental composition of rocks and soils, and this information, combined with the mineralogical data from other instruments (e.g., the mini-TES), allows rock types to be inferred, which in turn provides information about the local surface geology and morphology. Without the rover and its APXS, any surface observations made would be limited to those available from the lander instrument suite, and thus there would be no information collected regarding elemental composition of rocks and soils on the surface of Mars. The removal of the rover would severely limit a Mars Surveyor Program goal of further characterizing the Martian surface at various sites on the planet. Loss of the APXS data concerning elemental composition of Martian surface material would also weaken the correlation of orbital observational data with ground data to better calibrate the results of orbital observations. Additionally, removal of the rover would preclude a demonstration and verification of autonomous rover operation, a characteristic that is critical to future sample collection strategies via the more advanced rover planned for future missions. Eliminating the rover would also limit the possibilities for achieving specific education and public outreach objectives.

Assessment of the Orbiter-Only Mission Alternative. Removal of the lander and rover from the MS 01 mission would eliminate all capabilities of the mission to perform in situ observations and experiments on the surface of Mars. This would eliminate the capability to achieve all the science objectives relating to local surface geology, morphology and chemical composition, and the objectives relating to future human exploration of Mars (see Section 2.1). The complete elimination of in situ science from the MS 01 mission would have a significant adverse impact on a key Mars Surveyor Program goal of further characterizing the Martian surface at various sites on the planet. Also lost would be the ability to correlate global observational data obtained from orbit with local, in situ information that could have been developed by the lander and rover instruments and experiments, and the higher resolution surface morphology information needed to make assessments of local geologic processes. Additionally, removal of the rover would preclude a demonstration and verification of autonomous rover operation, a characteristic that is critical to future sample collection strategies via the more advanced rover planned for future missions. In short, the Orbiter-Only Mission Alternative would address only approximately ten percent of the MS 01 mission's objectives. Eliminating the lander and rover would severely limit the possibilities for achieving specific education and public outreach objectives.

Assessment of the No-Action Alternative. Under the No-Action Alternative, planning and preparations for the MS 01 mission would cease and the orbiter, lander, and rover would not be launched during the 2001 opportunity. None of the science planned for the Proposed Action would be obtained. NASA has no other Mars missions at a stage of development that could be substituted for the Proposed Action or alternatives, and the favorable launch opportunity (which occurs every 26 months) for 2001 would be lost to the Mars Surveyor Program and to the overall Mars exploration effort.